

Radiation dosimetry

1) Absorbed Dose

- Energy deposited per unit mass of the material by secondary electrons
- Apply to all directly and indirectly ionizing radiation
- Used to define quantity of radiation delivered to specific point of the material
- Unit = gray = 1 J/Kg
 - Rad: $1 \text{ Gy} = 100 \text{ rads}$

2) Kerma

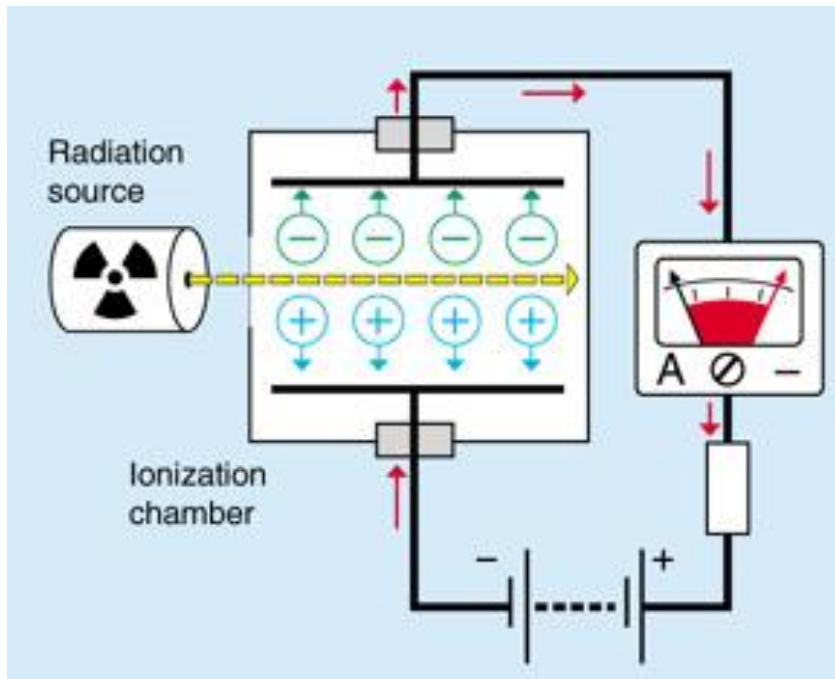
- Kinetic energy released in the matter.
- Also measured in grays
- = energy transferred per unit mass of the material from photons to electrons at specific location
- Only practical difference between kerma and absorbed dose is at very high energies (1Mev)
- For diagnostic energies they are equal

3) exposure

- Obsolete quantity
- Applies to x ray and gamma rays only
- Unit = roentgen = 10 mGy

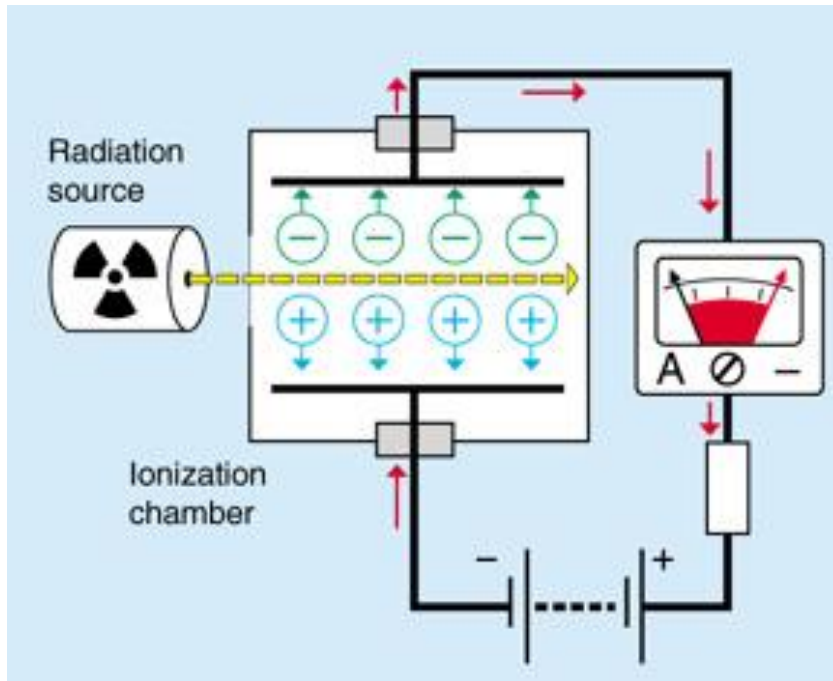
Ionization chamber

Device for detection of ionizing radiation by measuring the electric current generated when radiation ionizes the gas in the chamber and therefore makes it electrically conductive.



Components:

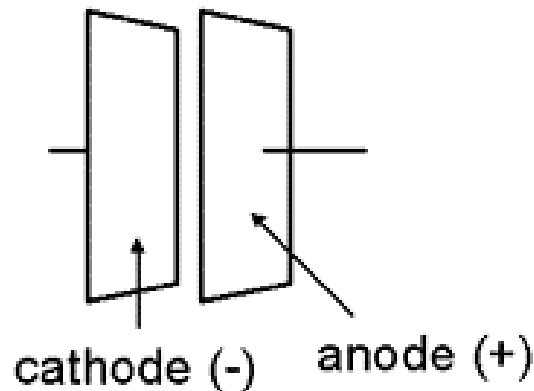
- 1) Plastic outer wall surrounding air filled cavity
- 2) Insulator separating the wall from the electrodes
- 3) Electrodes (cathode and anode)
- 4) Electrometer



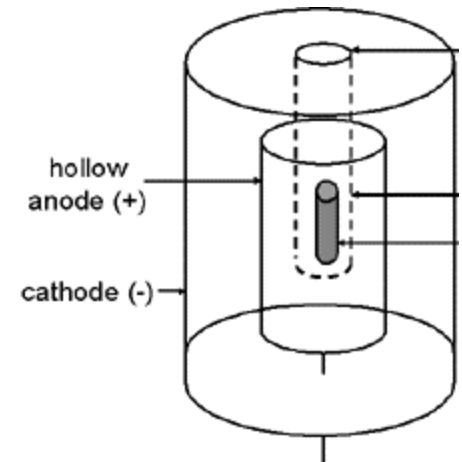
- 1) X ray photon is absorbed in the wall liberating secondary electron
- 2) Secondary electron produce ion pairs along its track inside the chamber
- 3) Ions are separated by applying voltage between electrodes
- 4) Ionization current is measured by electrometer
- 5) Current is \propto air kerma rate
total charge collected is \propto air kerma

Notes

- 1) chamber wall is made of plastic because it matches the air in the terms effective atomic number, so that it attenuates the photons to the same degree
- 2) chamber wall must be sufficiently thick so that electrons produced outside the chamber will not penetrate the wall (0.2 mm)
- 3) two types:



Parallel plate



cylindrical

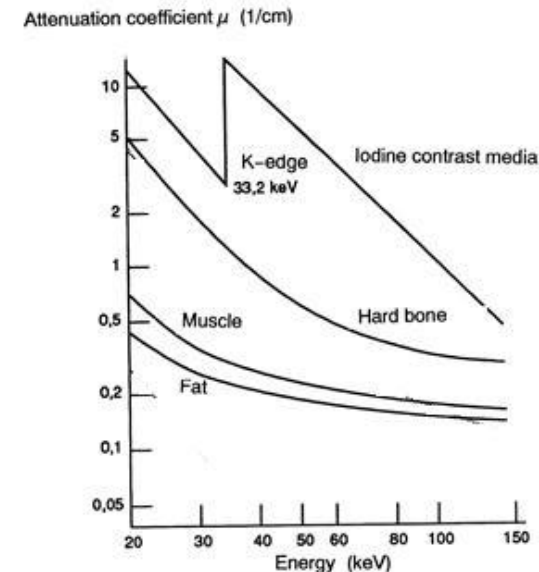
- 4) sensitivity of ion chamber (charge per unit air kerma) is proportional to its volume
e.g 10-30 cm³ to measure radiation beam
150 cm³ to measure scatter radiation

How to measure absorbed dose in tissues

- Absorption dose in tissues = absorption dose in air X conversion factor
- Conversion factor depend on 1)Z 2)E (remember?)
- Conversion factor for muscle = 1 – 1.1 (same Z as air)
- Conversion factor for bone = 5 at low Kev , 1.2 at high Kev

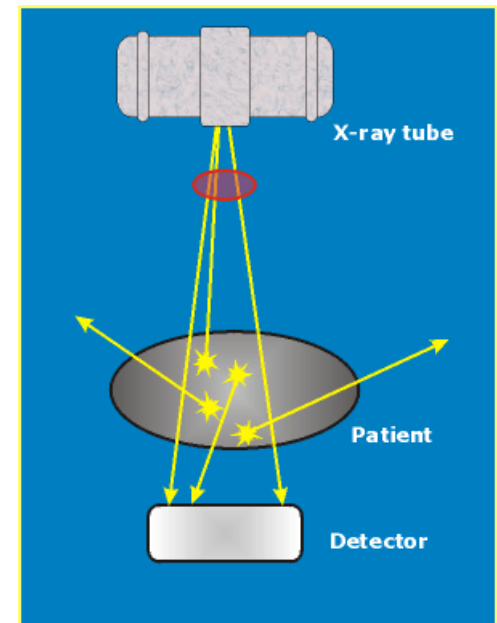
Why did we use air?

- 1)Z is close to tissues →easy to convert the absorbed dose
- 2) Applicable for wide range of energies
- 3)Applicable for large and small doses
- 4) available



Application of ionization chamber

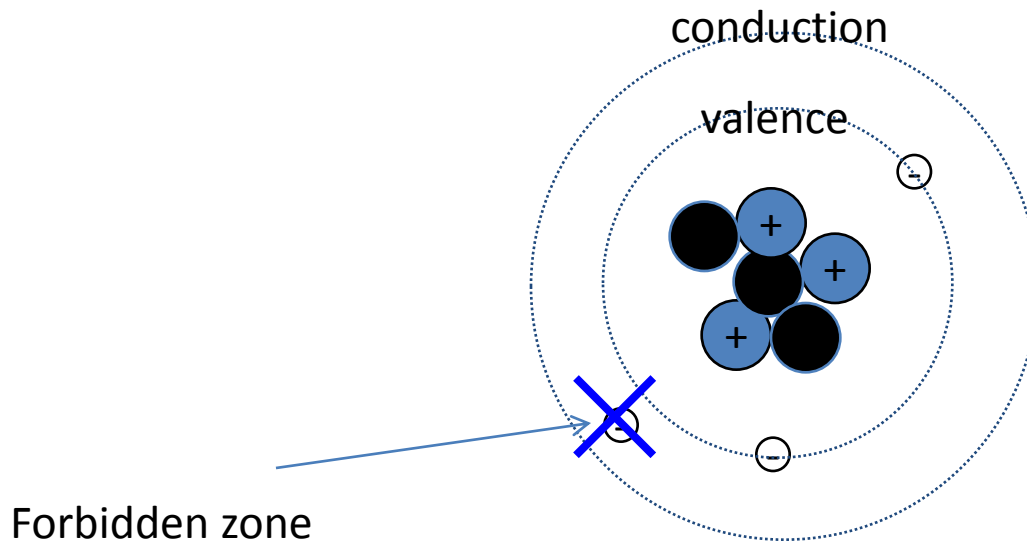
- Dose area product meter
 - Mounted in the collimator of X-ray tube
 - Its area is bigger than maximum beam size
 - The reading is proportional to the absorbed dose and the area of the beam
 - Unit = Gy cm^2



X-ray image

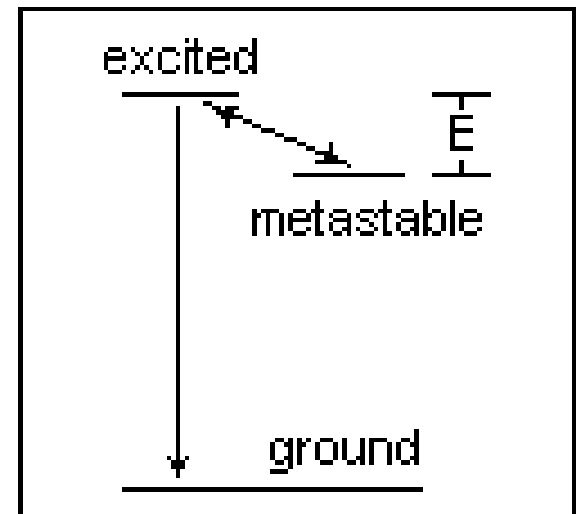
luminescence

- Process in which a material absorbs energy and re-emit that energy in the form of visible light
- Photo-luminescence : the absorbed energy is from radiation source
- Two types:
 - 1) Fluorescence : instantaneous emission of light after energy input
 - 2) Phosphorescence : delayed light emission (after-glow)
- The Material which has luminescent properties = phosphor

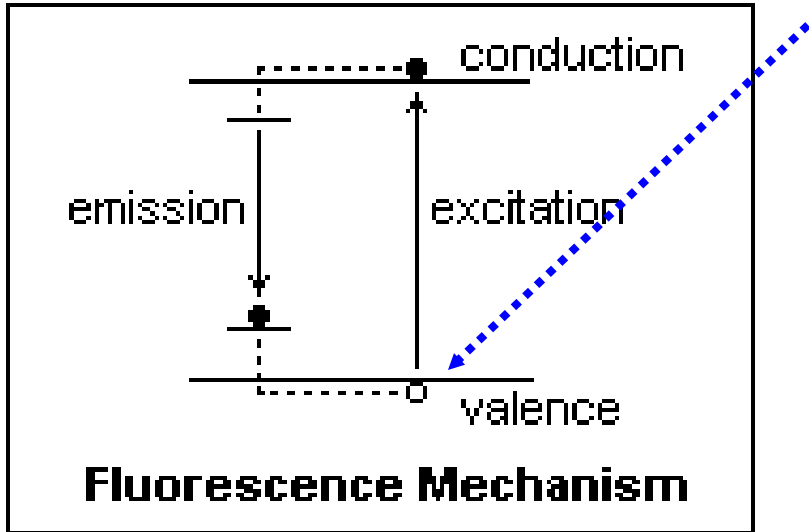


Forbidden zone

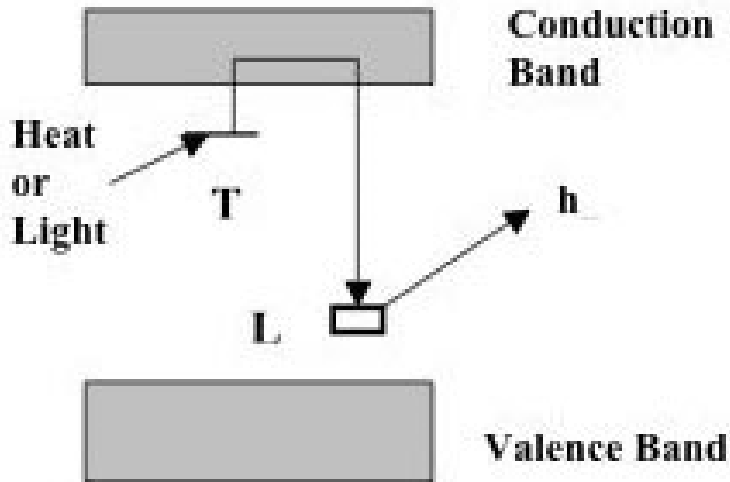
- Valence shell = outermost shell occupied with electrons
- Conduction band = next higher energy shell (vacant)
- Forbidden zone = zone between the two shells (could not be occupied by electrons)
- Electron traps = impurities introduced into phosphor that can trap electrons into the forbidden zone



Luminescence process



- 1) X-ray is absorbed and produce recoil electron and photoelectron
- 2) The secondary electron will cause atom excitation (electron is raised to conduction band)
- 3) Electrons move down to the electron traps
- 4) Electrons returns backs to valence band and release energy in the form of light
- 5) Intensity of light emitted from the phosphor is \propto intensity of absorbed x-ray



Phosphors may:

- 1) Emit the light spontaneously
- 2) Emit the light following heating (thermoluminescence)
- 3) Emit light when exposed to a light source (photostimulable luminescence)

This idea is used in digital radiology and radiation detection (see later)

Patient dose and tube factors

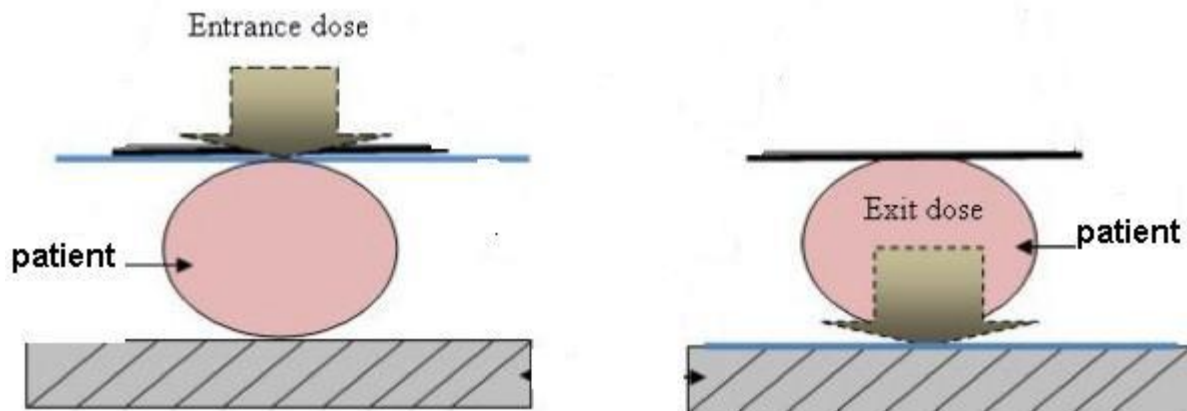
definitions

Entrance surface dose (ESD) : radiation dose to the proximal skin surface

Exit dose = film dose = dose emerging from the patient

ESD is higher than exit dose e.g. ESD/exit dose = 100 for x-ray skull

Our aim is to decrease ESD without affecting exit dose (and so image quality)



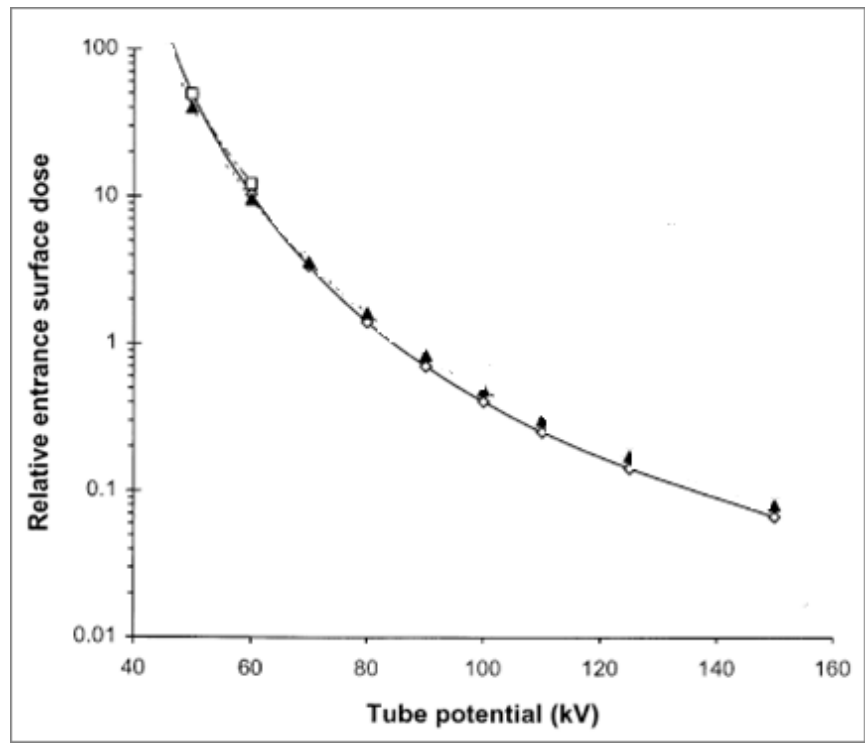
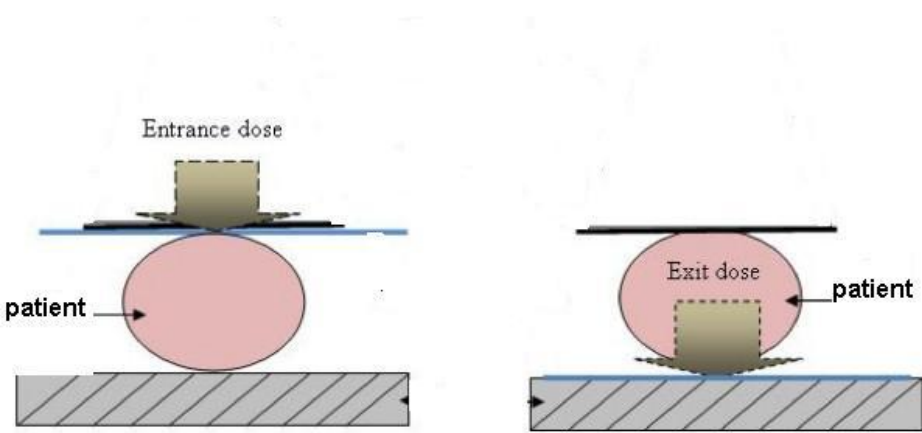
Factors affecting patient's dose

- 1) mA : increase mA → increase x ray intensity
→ increase patient dose
- 2) Filtration : decrease skin dose

- 3)Tube Kv:

Higher Kv →increase in beam quality (E)
(more penetrating beam more HVL)

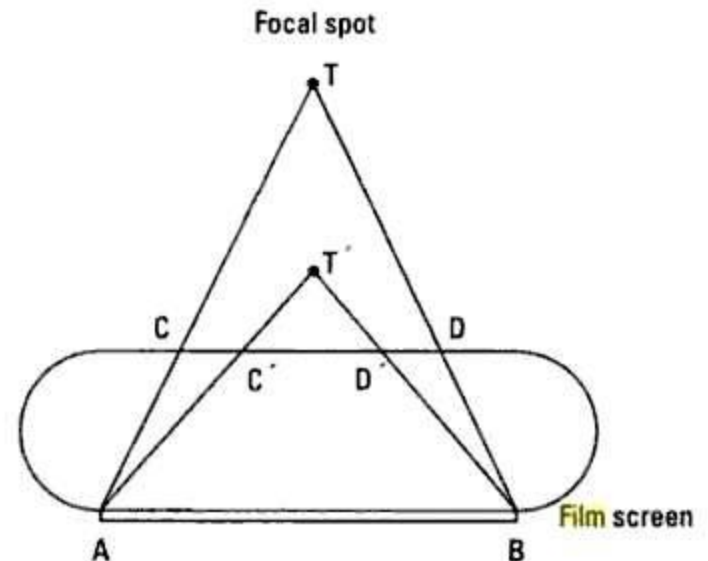
This means: for the same exit dose , we need less entrance dose
So that : mA is decreased to reach the same film blackening
So that patient dose is reduced



- 4) focus film distance:

Increase FFD \rightarrow the radiation is spread over larger surface area of the skin \rightarrow lower skin dose

N.B: Increase FFD requires increase in mA
(inverse square law) \rightarrow increase of tube load
(not patient dose)



Essential parameters influencing patient exposure

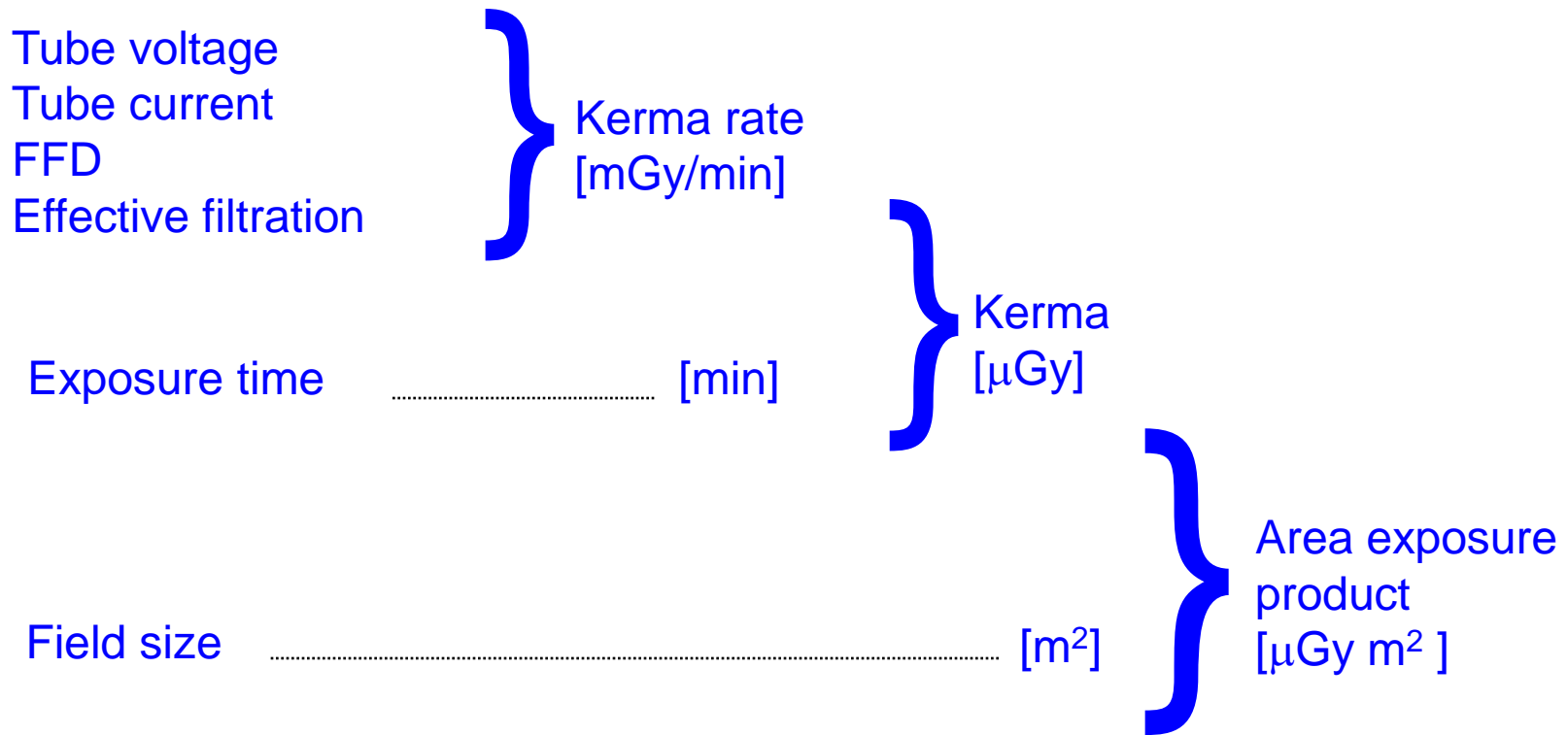


Image quality

Image noise

- **Random** variation in image density.
- produce variation in the density of a displayed image even when no image detail is present (unrelated to the structure imaged)
- This variation is usually random and has no particular pattern. And , it reduces image quality (gives an image a mottled, grainy, textured appearance)



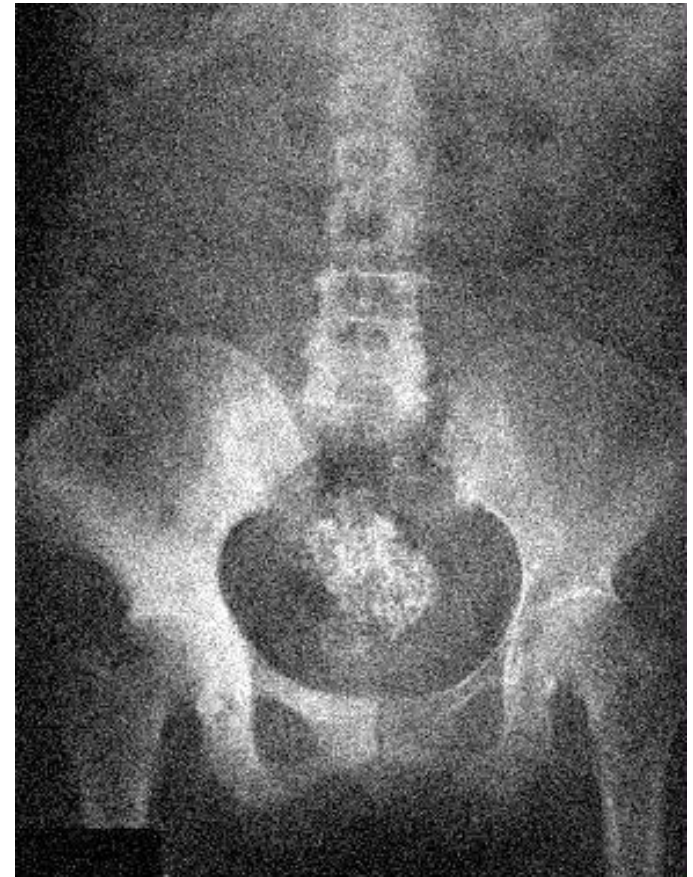
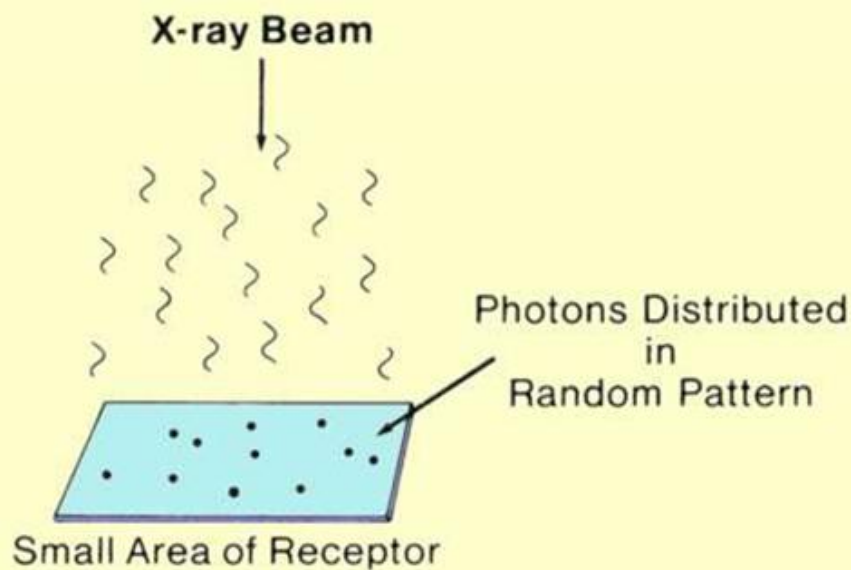
Types of noise

1) Quantum noise = mottle

Cause: random x-ray emission \rightarrow statistical fluctuations in # of photons/ unit area absorbed by receptor

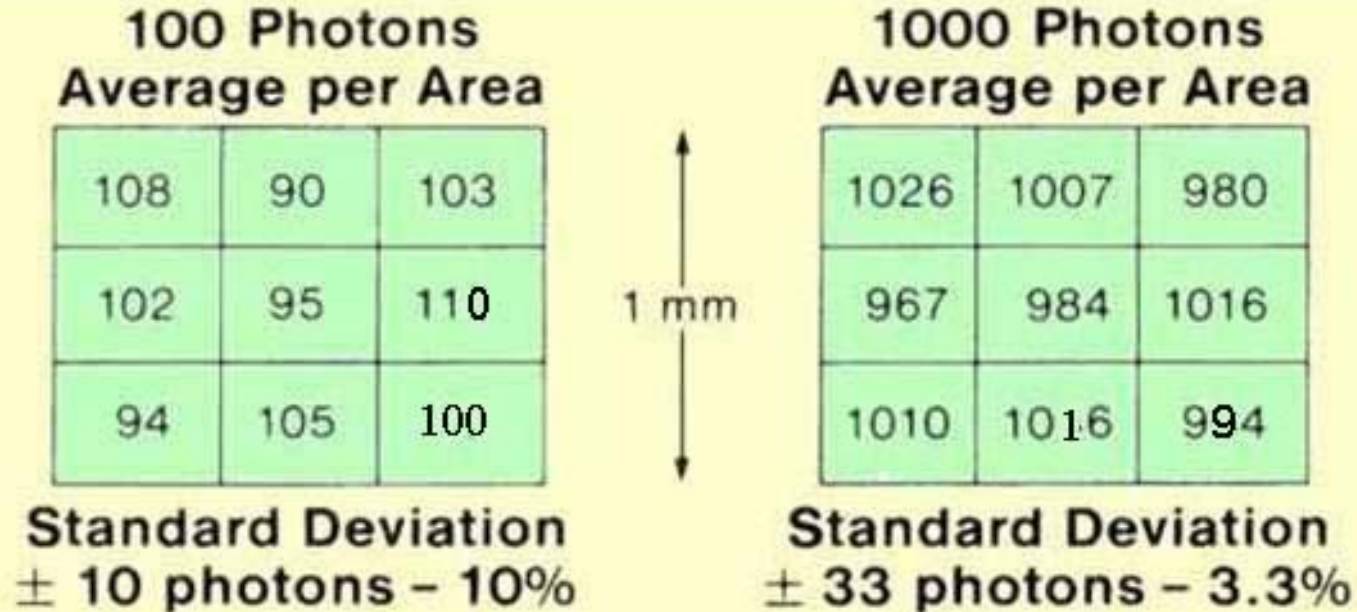
2) structured noise (see film screen)

3) Electronic noise: due to instability of electronic circuits



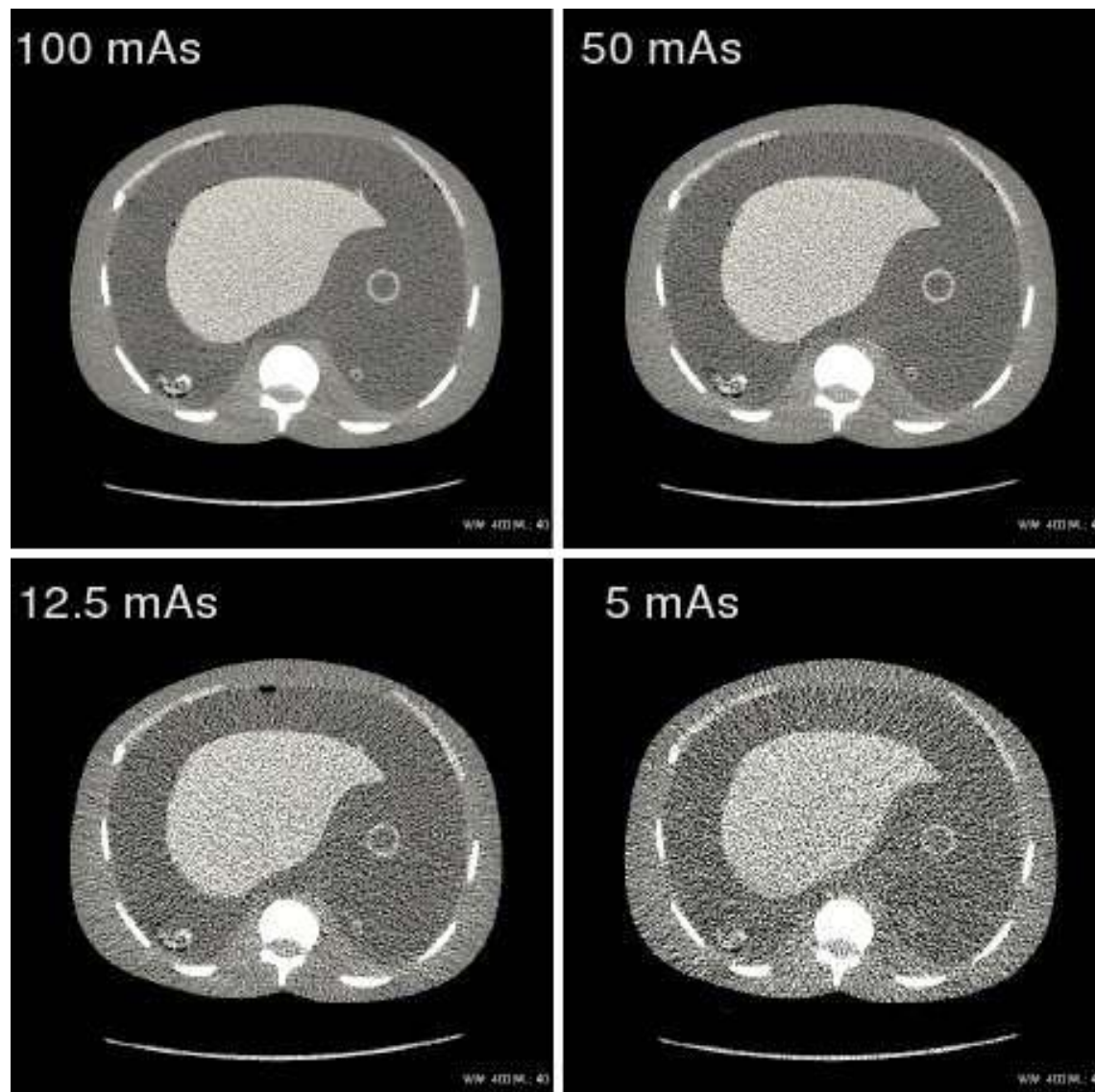
Quantum noise

- If average number of photons detected = $M \rightarrow$ variation between receptors (standard deviation) = \sqrt{M} (random process)
- The lower the number of photons detected \rightarrow the greater will be the variation in signal (\sqrt{M}/M) and less will be the signal to noise ratio SNR (M/\sqrt{M})



Effect of mA on the noise

- If mAs is reduced \rightarrow number of photons are reduced $\rightarrow M/\sqrt{M}$ is reduced (SNR)
- If mAs is reduced by $\frac{1}{2}$
 - noise increases by $\sqrt{2} = 1.414 \rightarrow$ (40% increase)



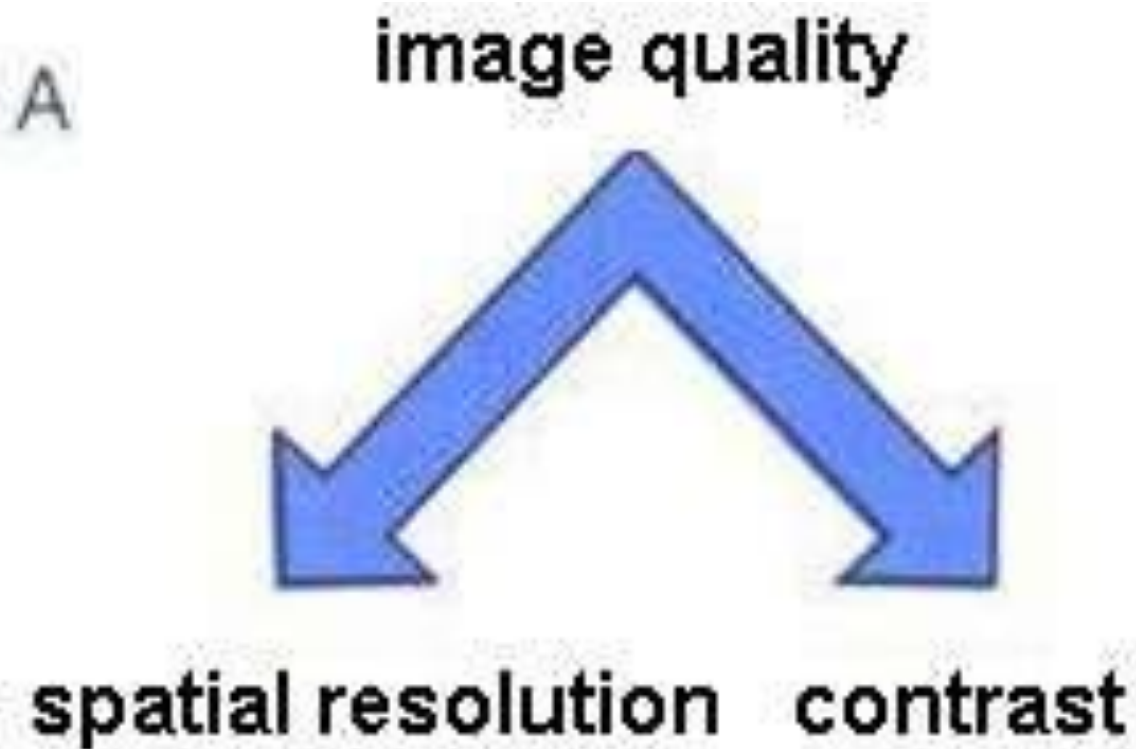
Remember : it is about quantity not quality

Effect of KVp on the noise

- Raising the kilovoltage → lower mAs is used → less x-ray photons exposing film
- higher quantum mottle and less SNR

- Effects of noise:
 - 1) Decrease the contrast resolution of the image
 - 2) Decrease visibility of low contrast regions
 - 3) Decrease visibility of fine details of the image

Image Quality



Contrast(= contrast resolution)

- Difference in density between areas on the radiograph, and so , ability to distinguish between them.
- Contrast depends on
 - subject contrast
 - film contrast (see film screen)
 - fog and scatter



Subject Contrast

- Difference in x-ray intensity transmitted through various parts of subject

- Depends on

- 1) Thickness difference
- 2) Density difference (All attenuation processes depend on density)
- 3) atomic number difference (P.E. $\sim Z^3$)
- 4) radiation quality (kVp, HVL)

• 2, 3, 4 are factors affecting μ

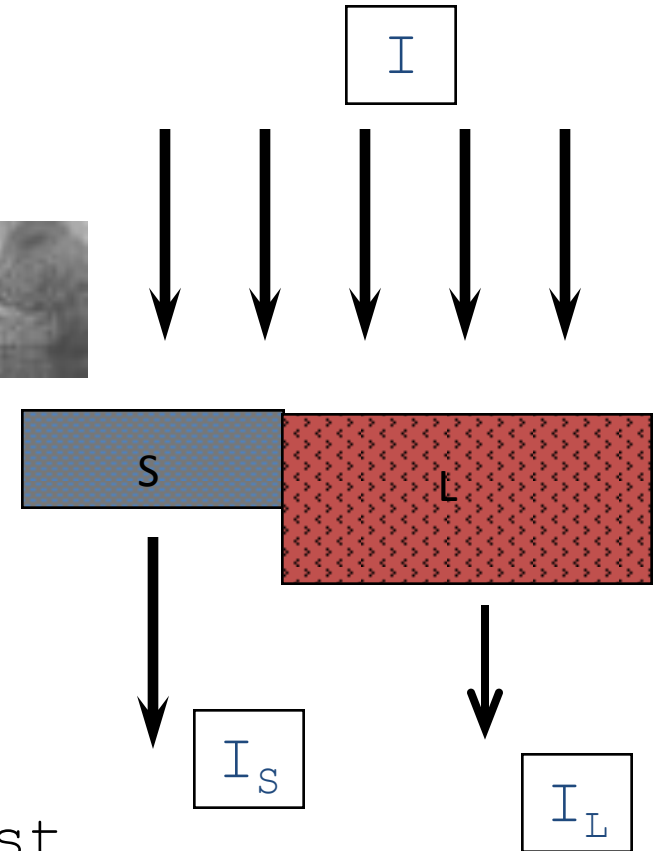
• So that : $C \propto (\mu_L - \mu_S) \times \text{thickness}$

In other words Subject Contrast

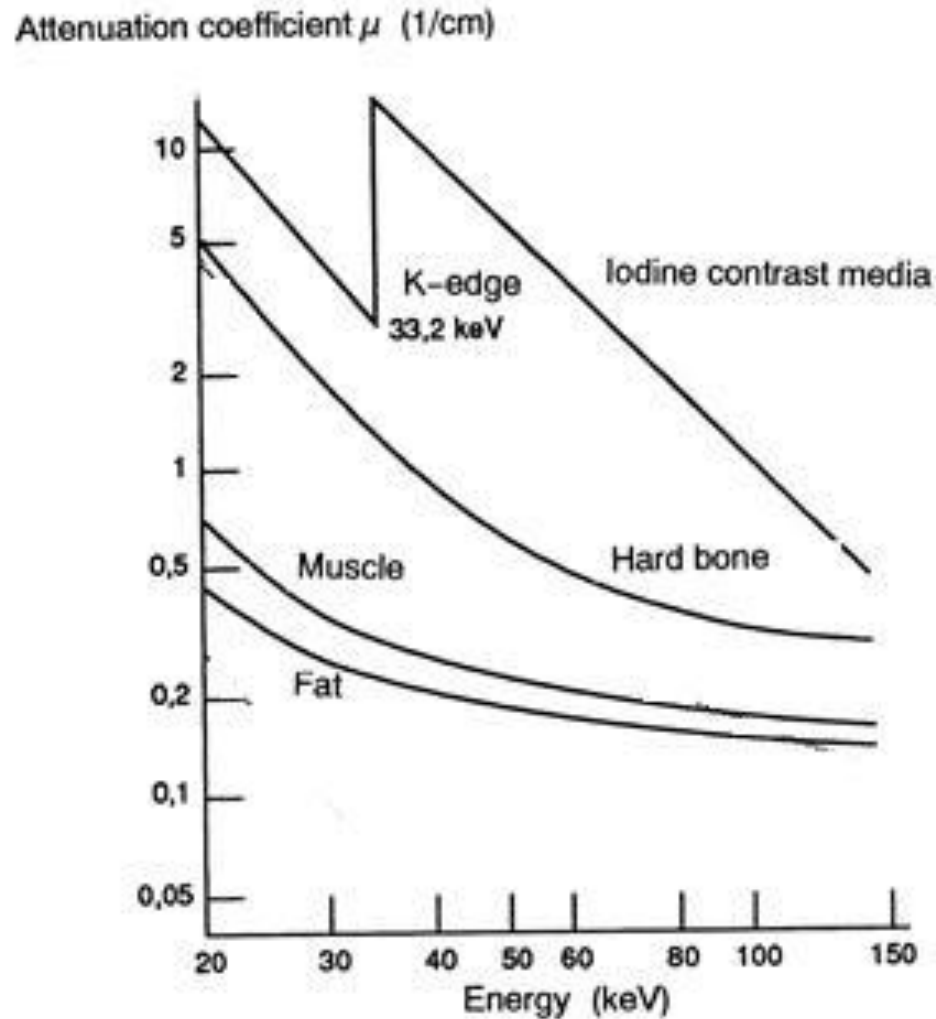
$$= I_S / I_L$$

$$I_L = \quad , \quad I_S =$$

(think)



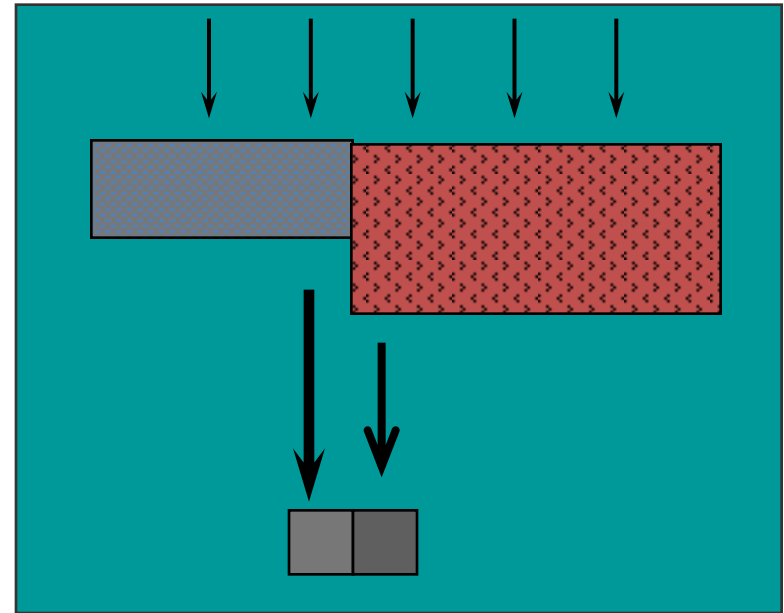
Subject Contrast & Radiation Quality



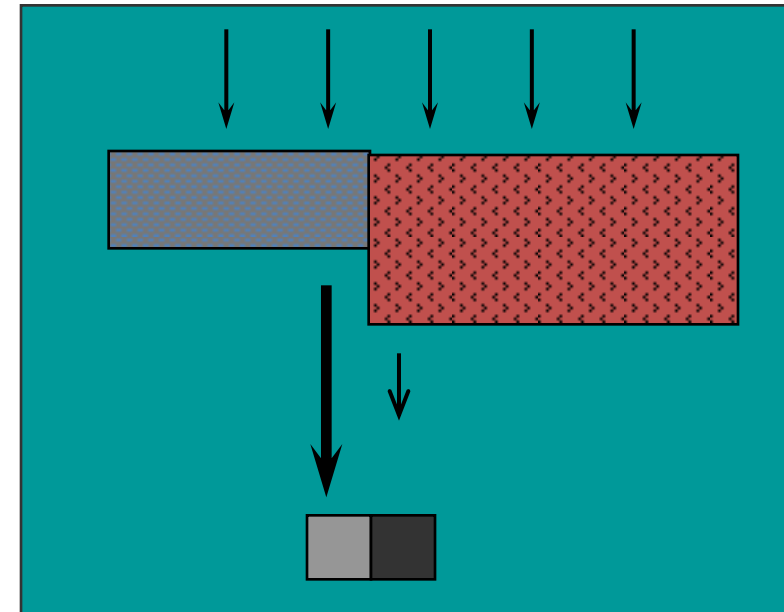
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Subject Contrast & Radiation Quality

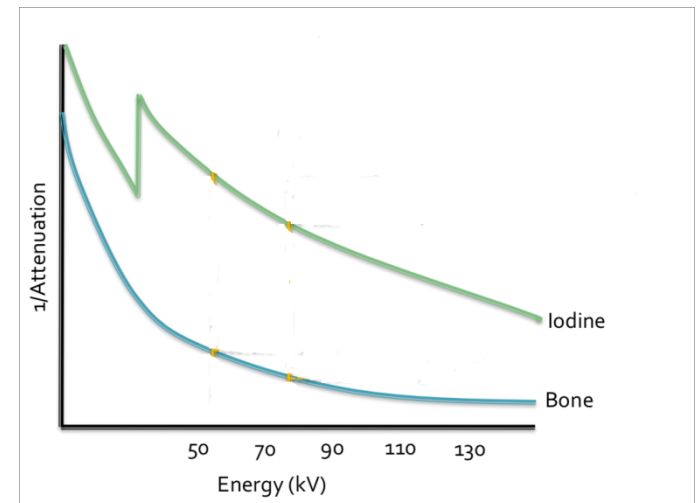
- high kVp = lower subject contrast



- low kVp = high subject contrast

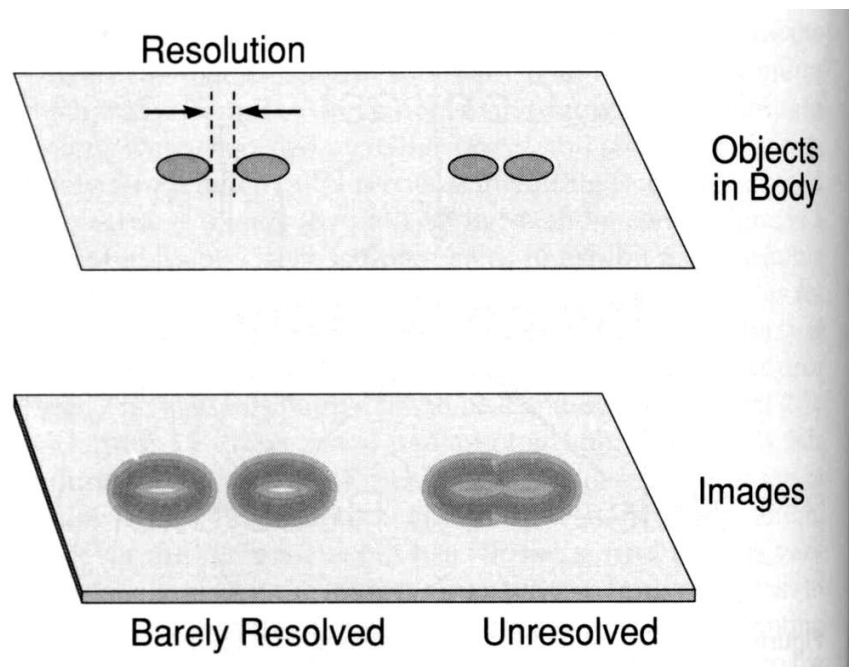


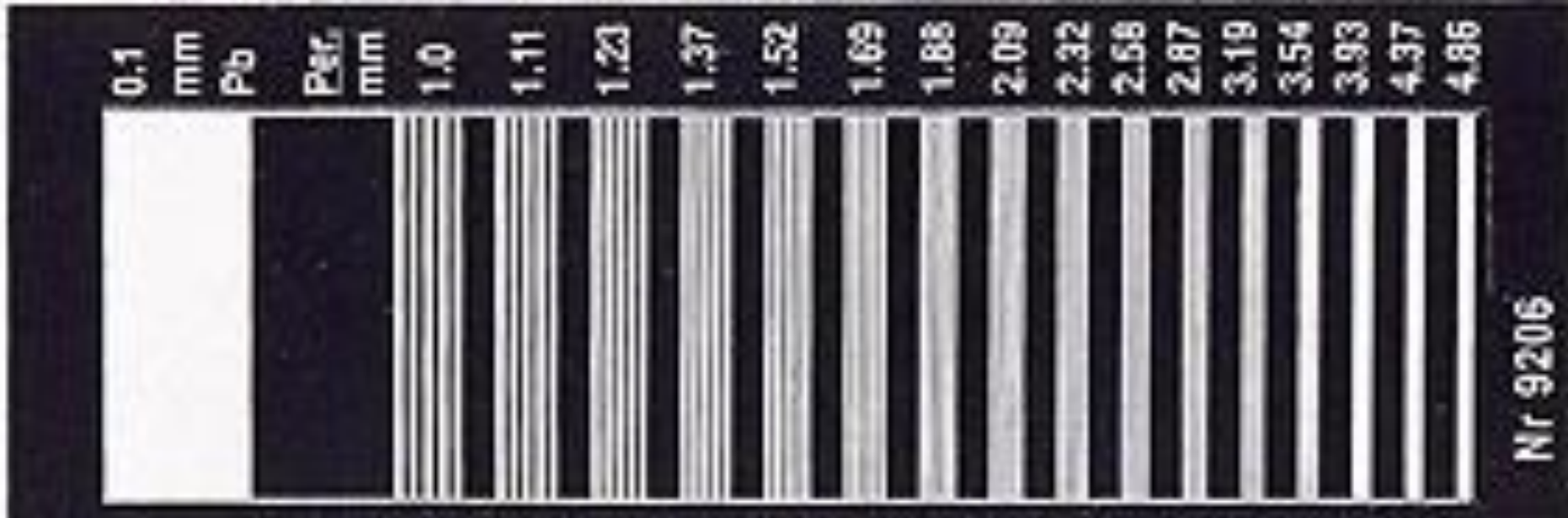
- So that to increase subject contrast
 - 1) Decrease Kvp
 - 2) USE CONTRAST MEDIA:
 - Increase Density difference and atomic number difference
 - absorption edge is just to the left of X-ray spectrum



Spatial Resolution

- Spatial Resolution is the ability to image small structures (ability to see fine details)





Grid test for testing spatial resolution

- Consists of equally spaced bars , the space between bars = width of the bars
- Line pair = bar + space
- Spatial frequency= number of line pairs per mm
- Consists of several groups of bars , of progressively higher spatial frequency
- Spatial resolution of the system = highest spatial frequency that can be resolved
- Example : system with spatial resolution of 1 lp.mm^{-1} has spatial resolution than system with resolution of 2 lp.mm^{-1}
- Smallest visible detail size = half of the inverse of the resolution expressed in this way
e.g. resolution of $10 \text{ lp.mm}^{-1} \rightarrow$ we are able to resolve detail as small as
- System with Smallest visible detail size of 0.05 mm has spatial resolution than system with detail size of 0.1 mm

Scattered radiation

Scattered radiation

Amount of scattered radiation reaching the film = (S)

Amount of primary radiation reaching the film = (P)

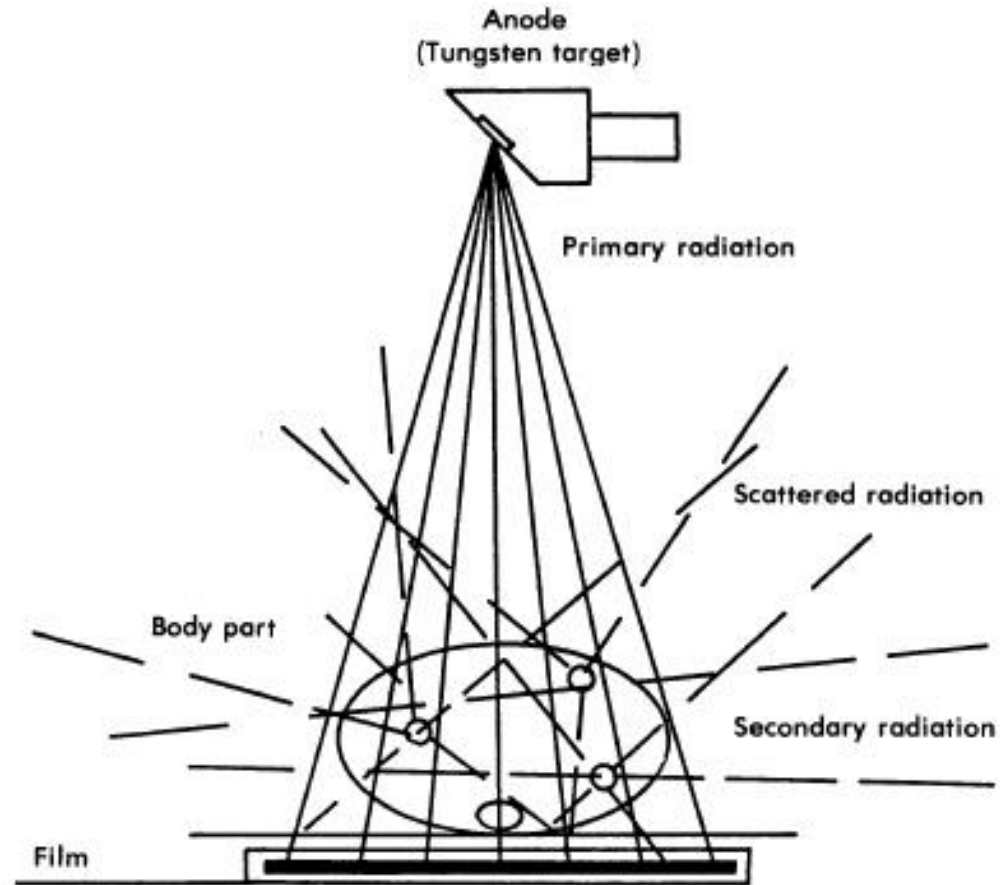
S/P depends on

1) Thickness of the patient : $\uparrow T \rightarrow \uparrow S/P$

2) Area of the beam : $\uparrow \text{area} \rightarrow \uparrow S/P$

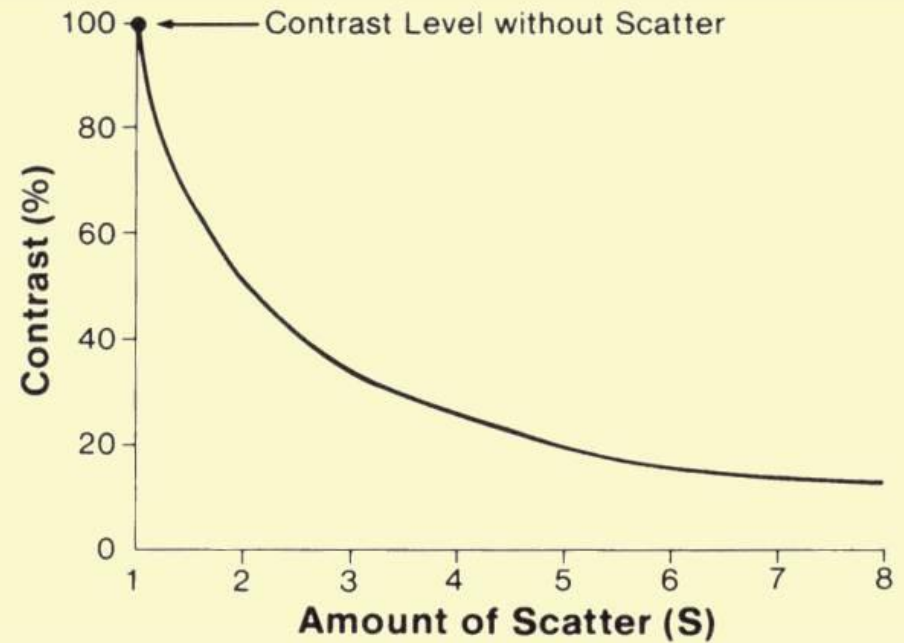
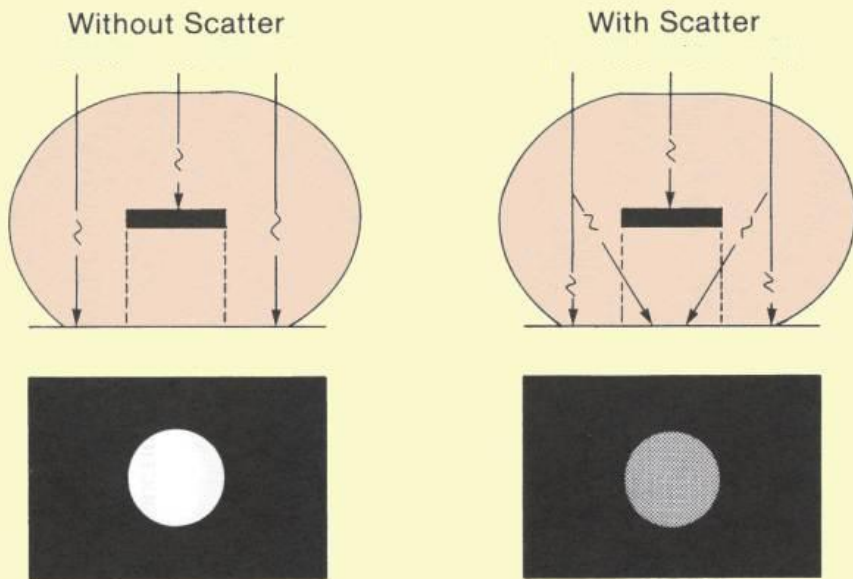
e.g. $S/P = 4$ for AP chest & $= 9$ for lateral pelvis

Source of scatter is



Effects of scattered radiation

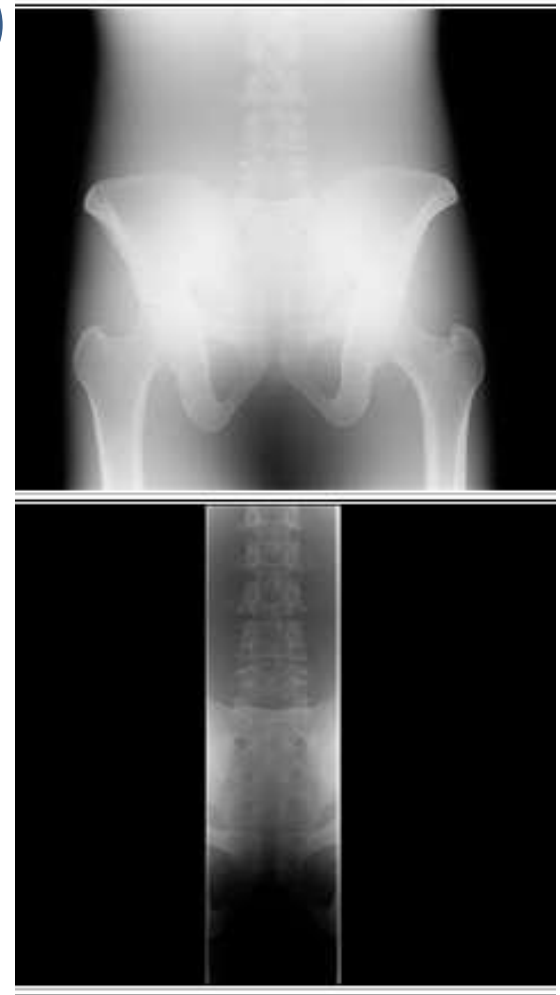
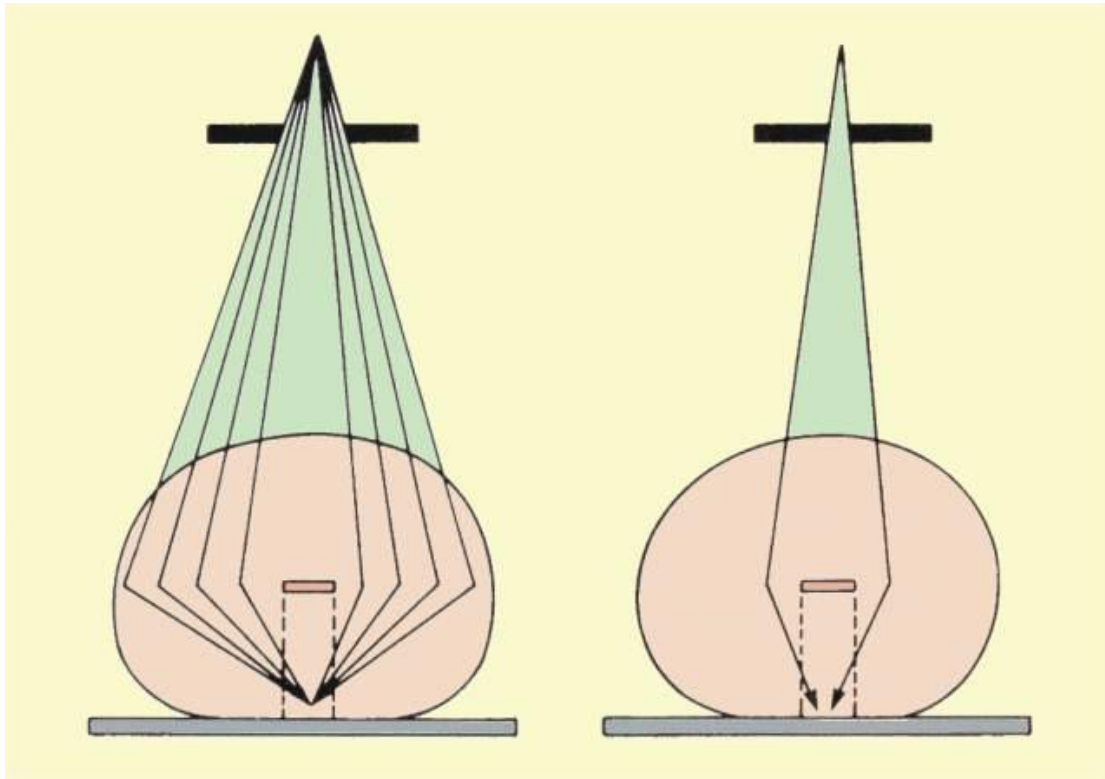
Decrease contrast of the image by factor of $(1+S/P)$



Scatter reduction

1) **COLLIMATION** (reduction of field area)

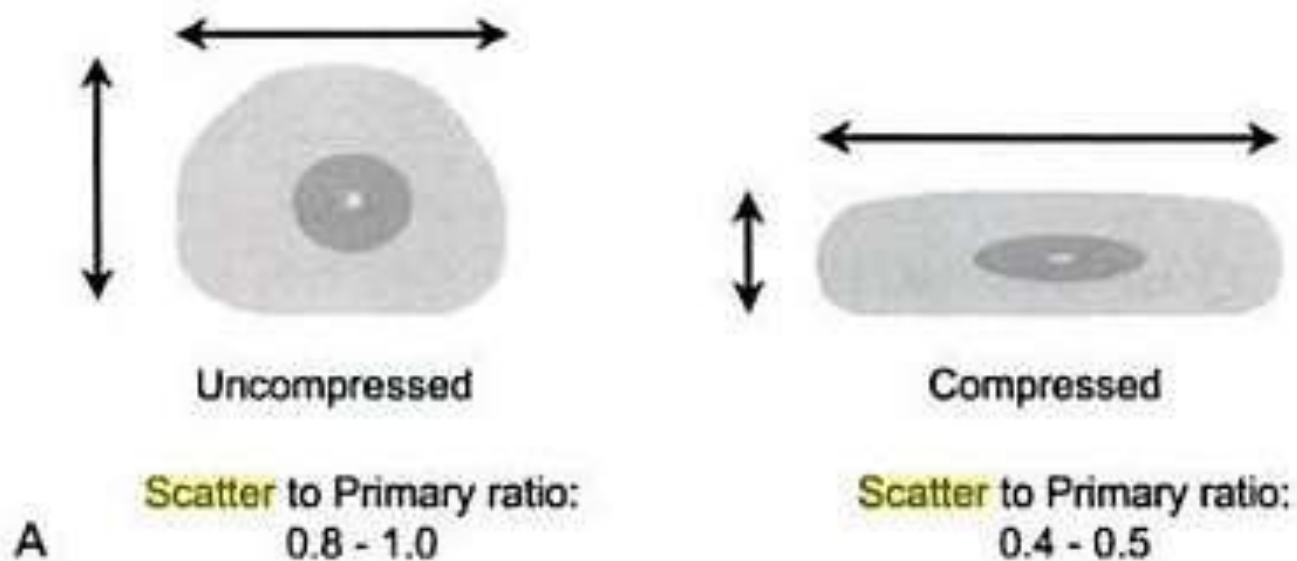
N.B: also reduce patient dose 😊



2) Tissue compression

N.B: also reduce patient dose 😊

e.g. mammography



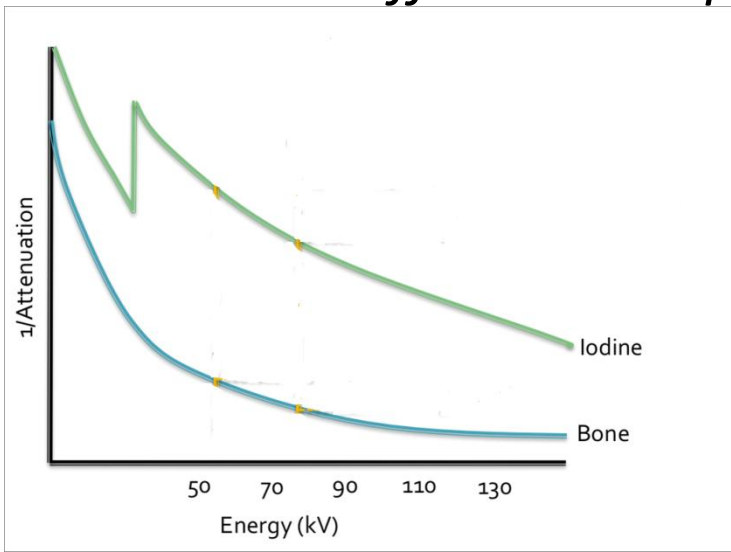
3) Decrease Kv

- Leads to decrease formation of scatter in forwards direction (towards the film)why?
- The produced scatter is less penetrative (less energetic) → less likely to reach the film

N.B: Why decreasing KV will increase the contrast

- decrease scattering

- increase differential in photoelectric absorption (more important)



N.B: also increase patient dose



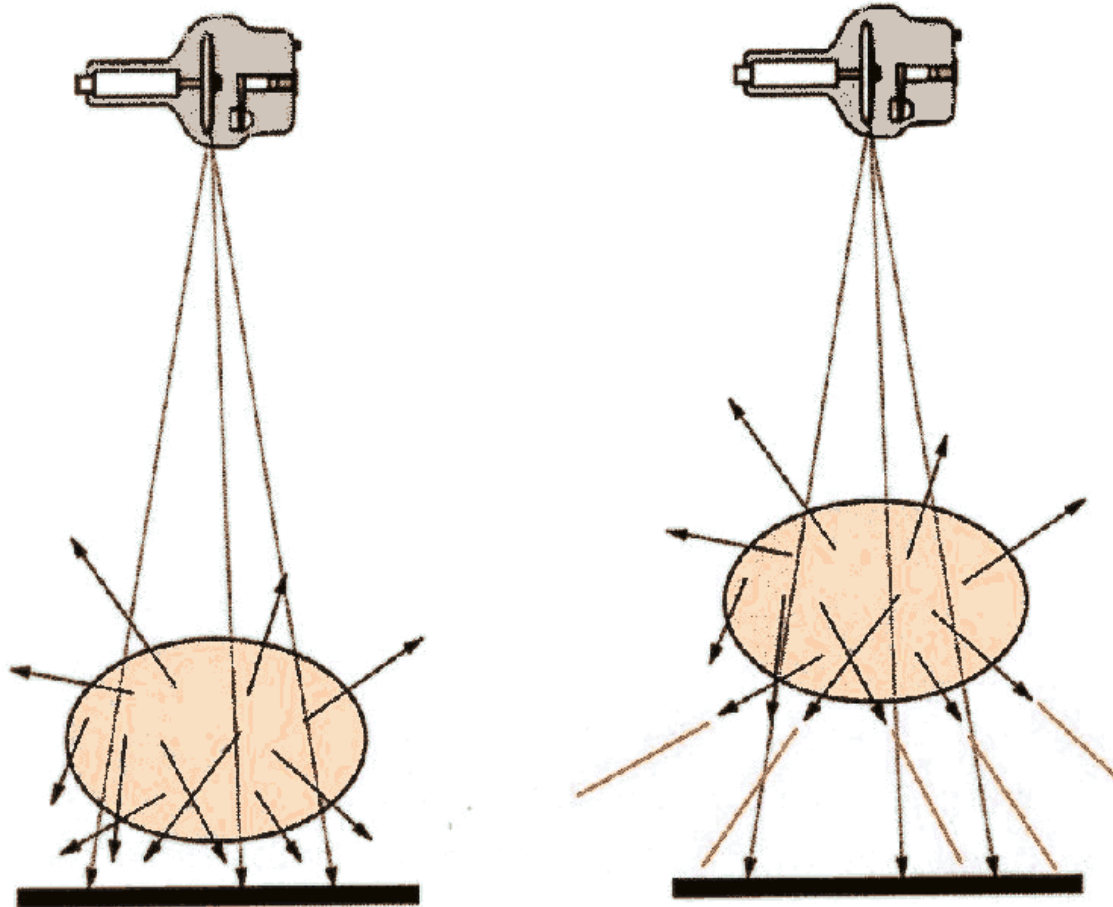
4) Air gap technique

5) Grids

N.B: 1,2,3 : decrease amount of scatter
produced

4,5 :decrease amount of the scatter that
reach the film (does not affect formation of
scatter)

Air gap technique



- Technique: Film is moved 30 cm away from the patient → scatter miss the film → contrast is improved

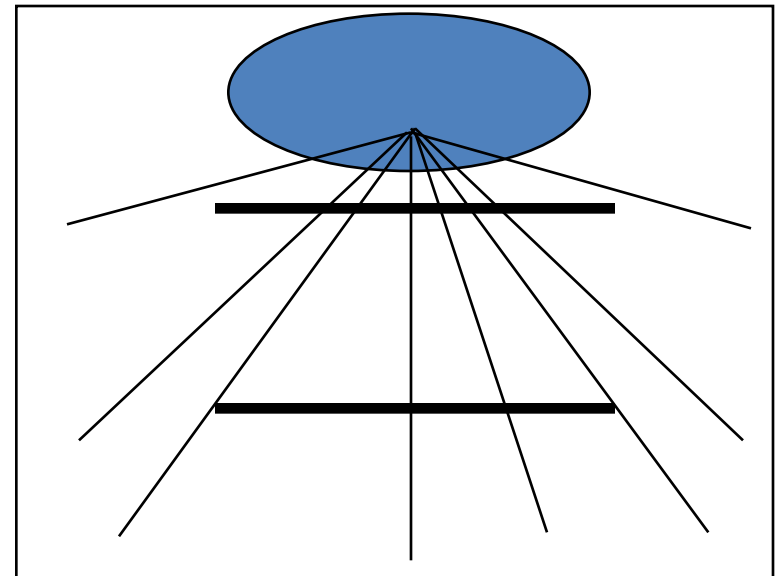
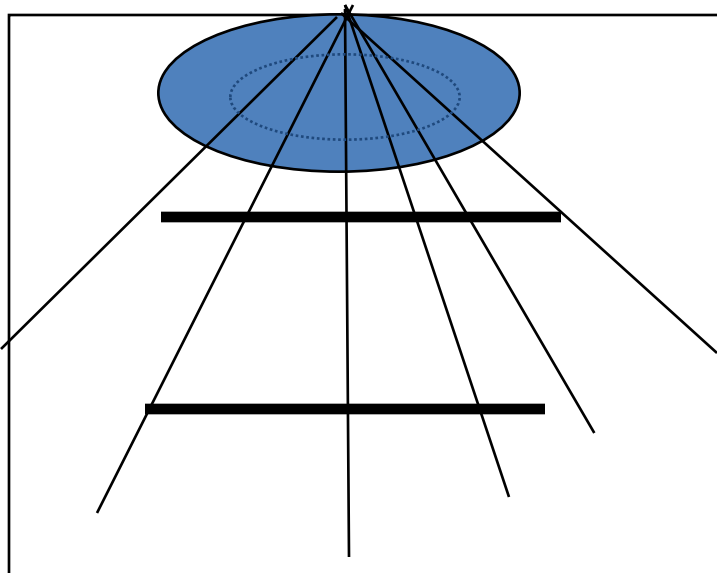
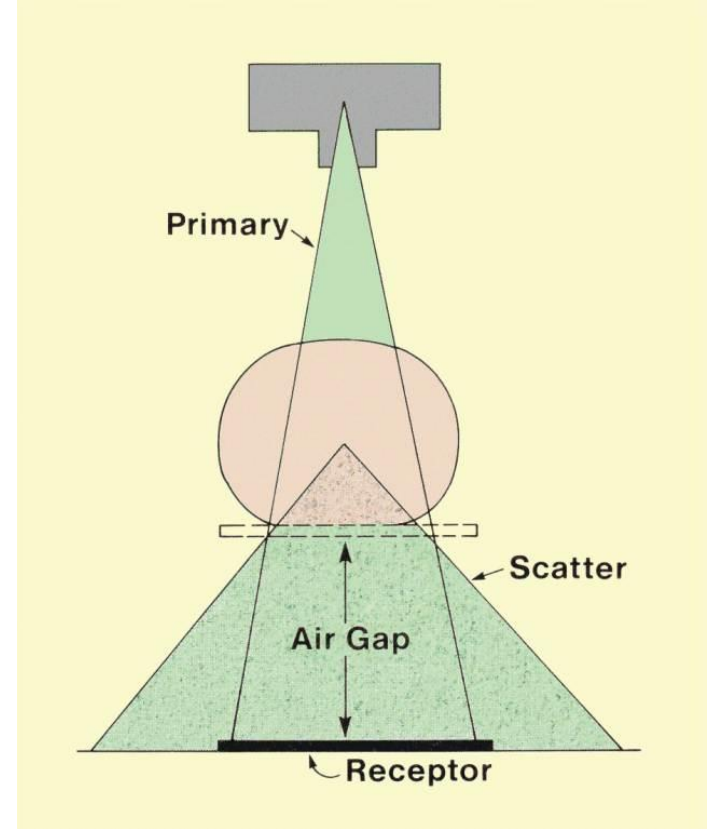
- Disadvantages:

- Require increase in mA (inverse-square) →

Patient exposure is increased ☹️

- Cause image magnification.

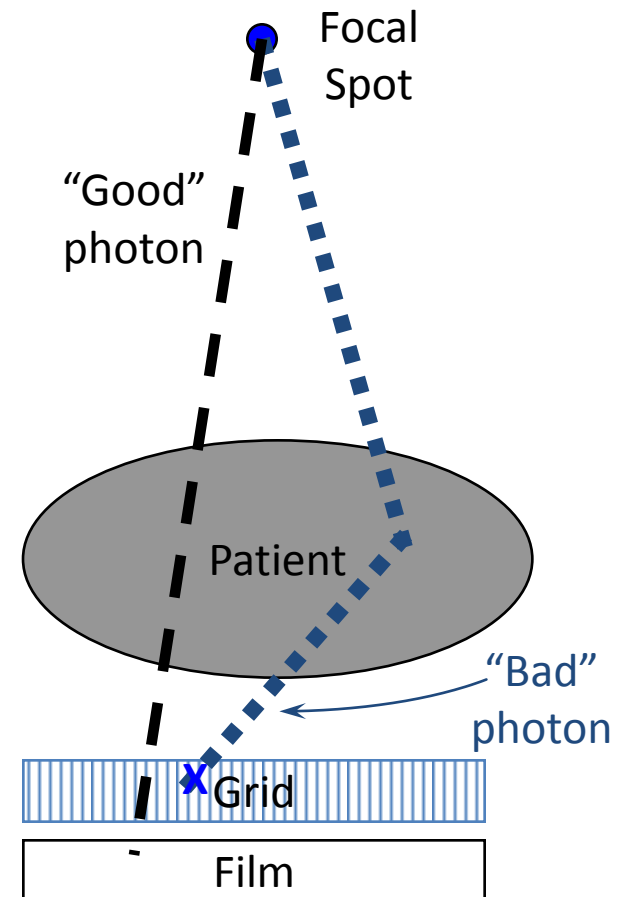
- N.B: very effective in removing scatter originating closest to film



Grids

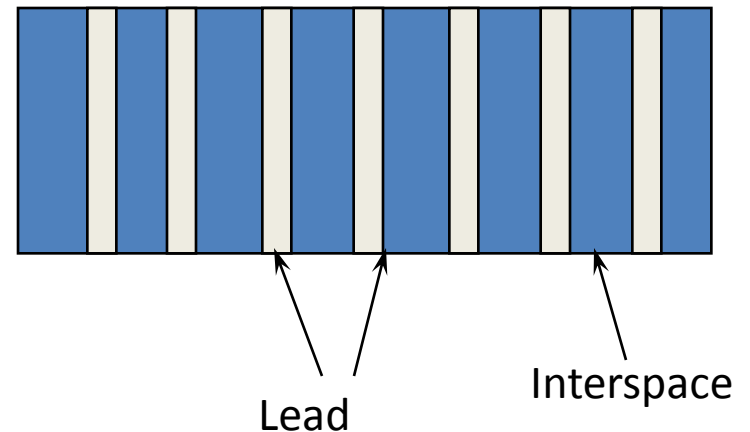
Purpose

- Directional filter for photons
- Ideal grid
 - passes all primary photons
 - photons coming from focal spot
 - blocks all secondary photons
 - photons not coming from focal spot

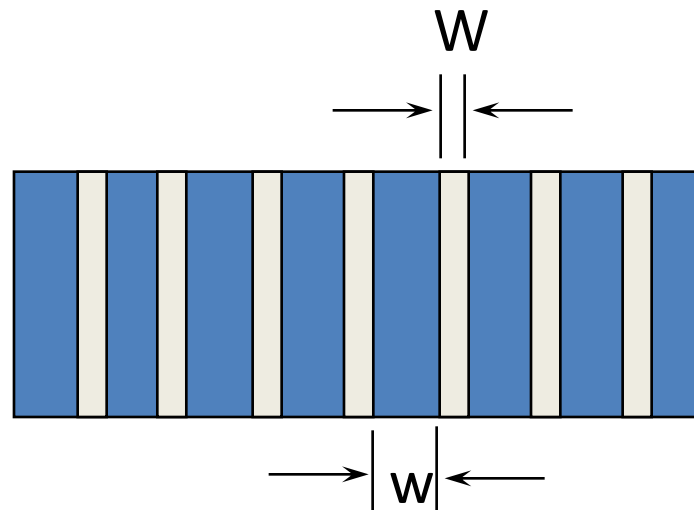


Grid Construction

- Lead
 - ~ .05mm thick upright strips
- Interspace
 - material between lead strips
 - maintains lead orientation
 - materials
 - Carbon fiber
 - aluminum

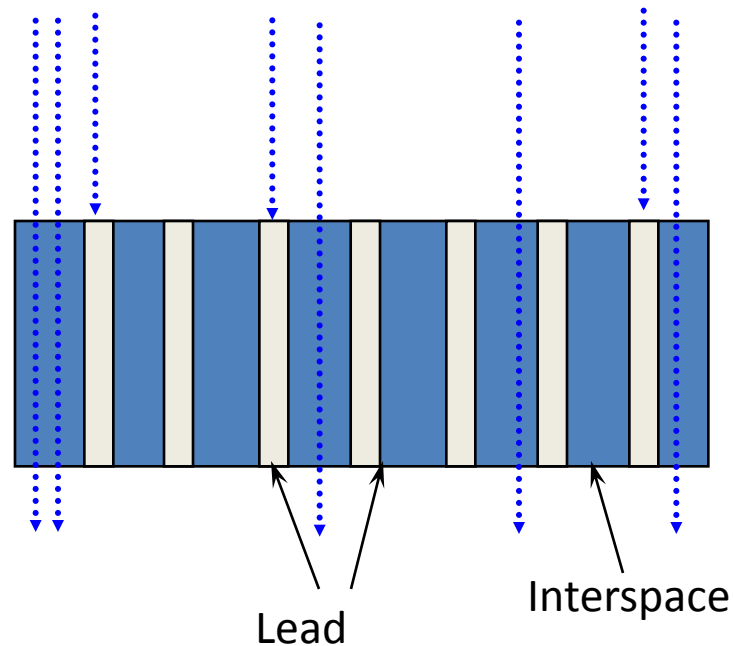


- **Grid Line density :**
- Number of stripes / cm (generally about 40 strips cm^{-1})
- So that : repetition interval = 0.25 mm
- Lead width = 0.06 mm
- Interspace = 0.19 mm



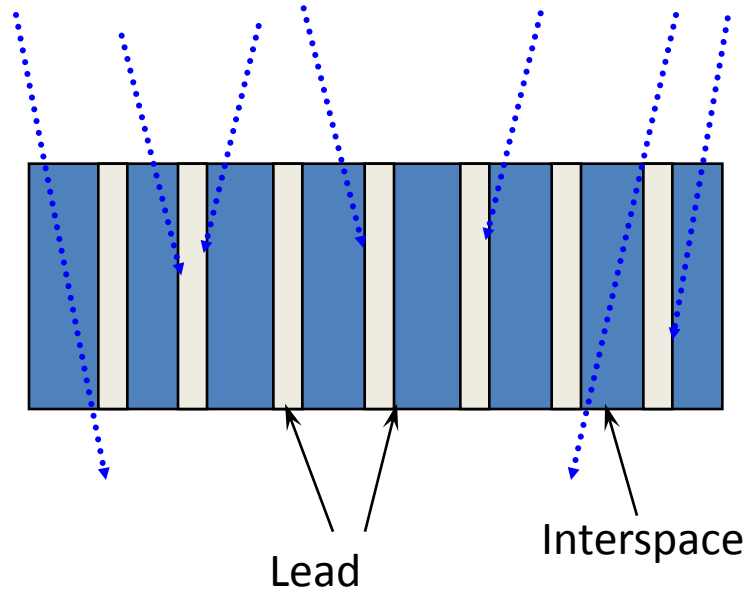
Ideal Grid

- passes all primary radiation
 - But in fact: lead strips block some primary



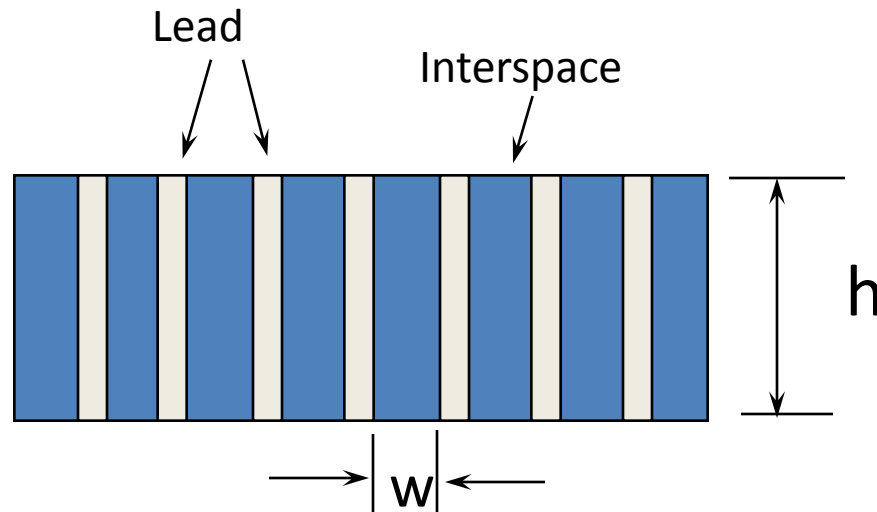
Ideal Grid

- block all scattered radiation
 - But in fact: lead strips permit some scatter to get through to film



Grid Ratio

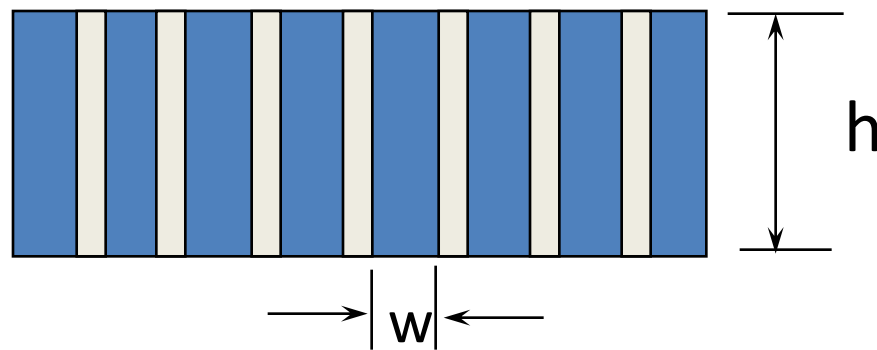
- Ratio of interspace height to width



$$\text{Grid ratio} = h / w$$

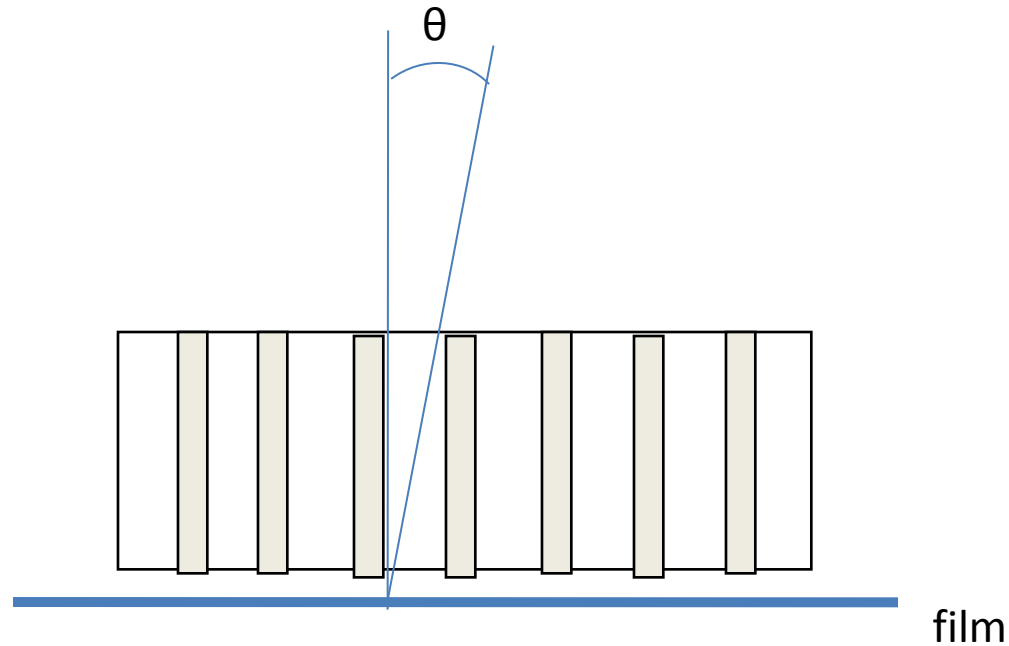
Grid Ratio

- Expressed as X:1
- Typical values
 - 8:1 to 12:1 for general work
 - 3:1 to 5:1 for mammography

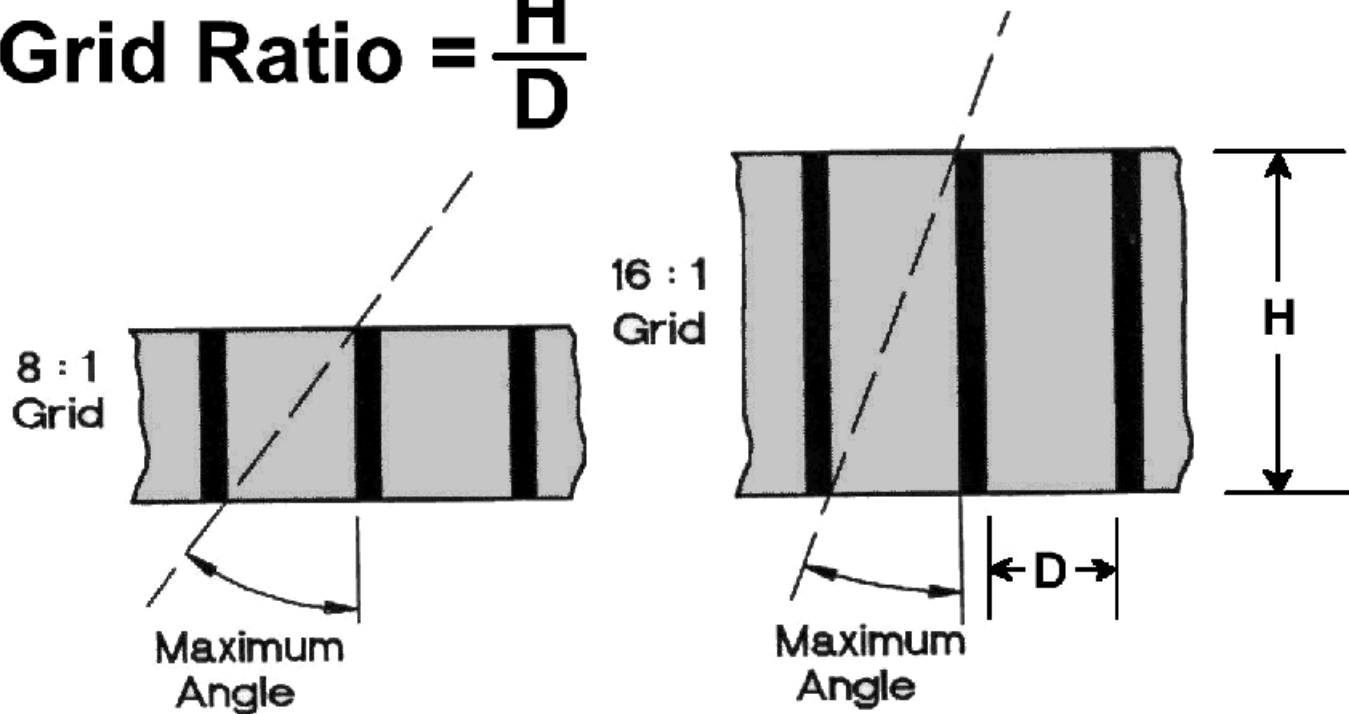


$$\text{Grid ratio} = h / w$$

Angle of acceptance : angle within which the scattered radiation can reach the film

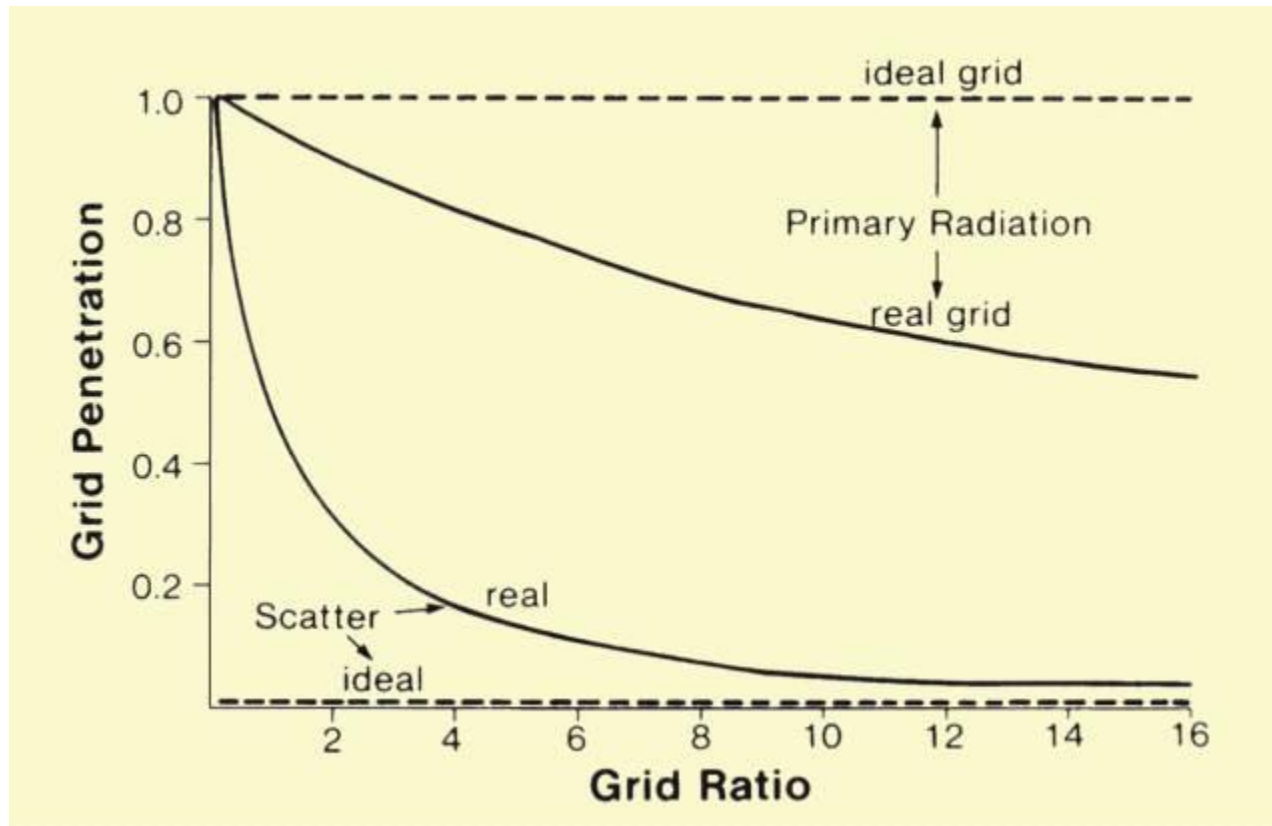


$$\text{Grid Ratio} = \frac{H}{D}$$



Note that

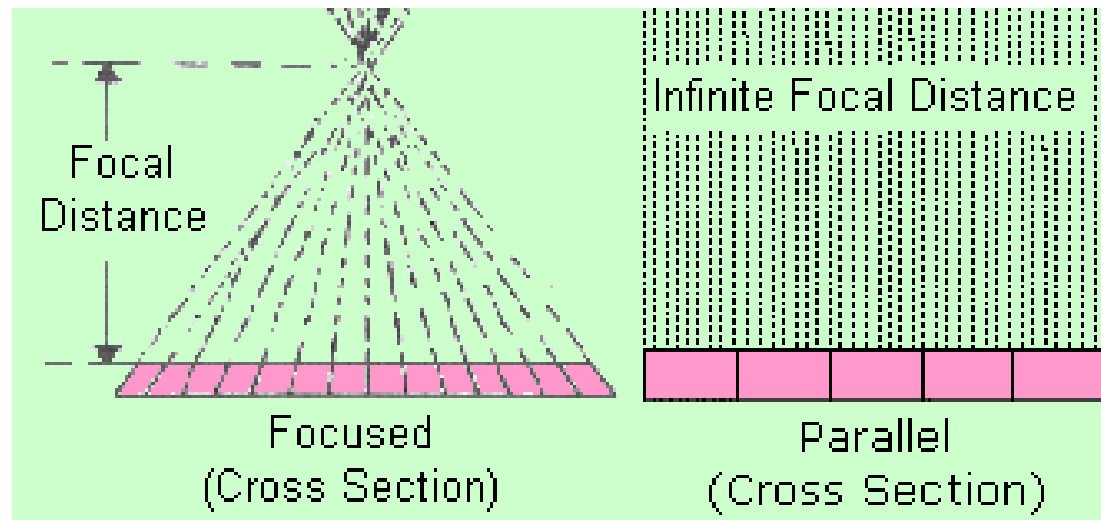
- The larger the grid ratio → the less the angle of acceptance → the more efficient is the grid → the more contrast of the film
- For large field radiology and high Kv → amount of scatter is increased → we must use higher grid ratio
- For thin body parts (limbs) and for children → amount of scatter is small → no grid is used
- Grid not used with air gap



- The larger the grid ratio → more attenuation of scatter radiation , but also , more attenuation of primary radiation

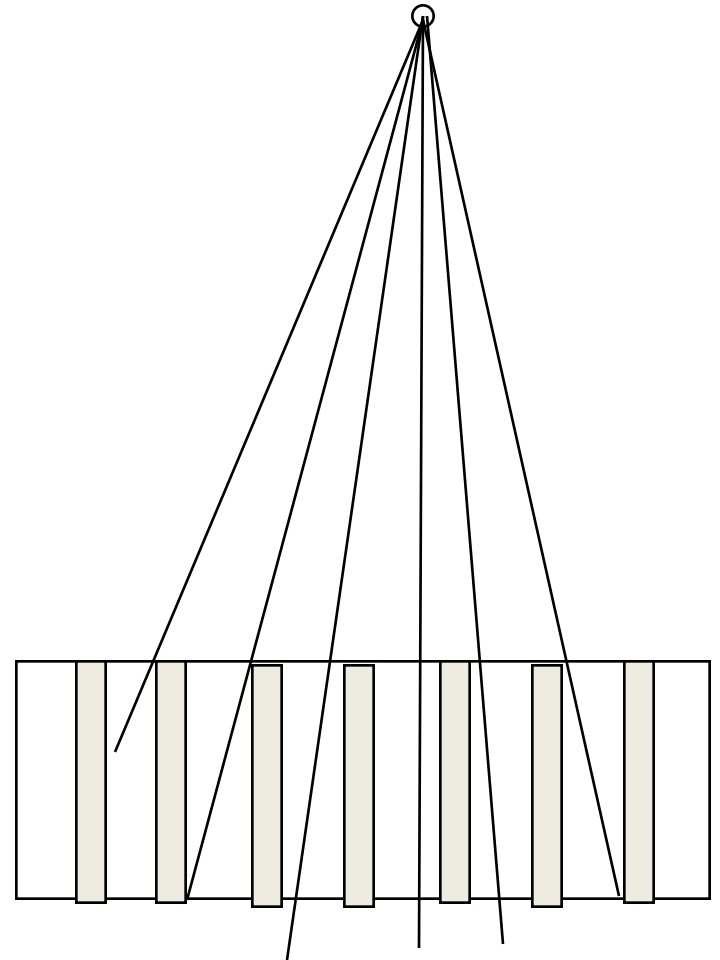
Grid Styles

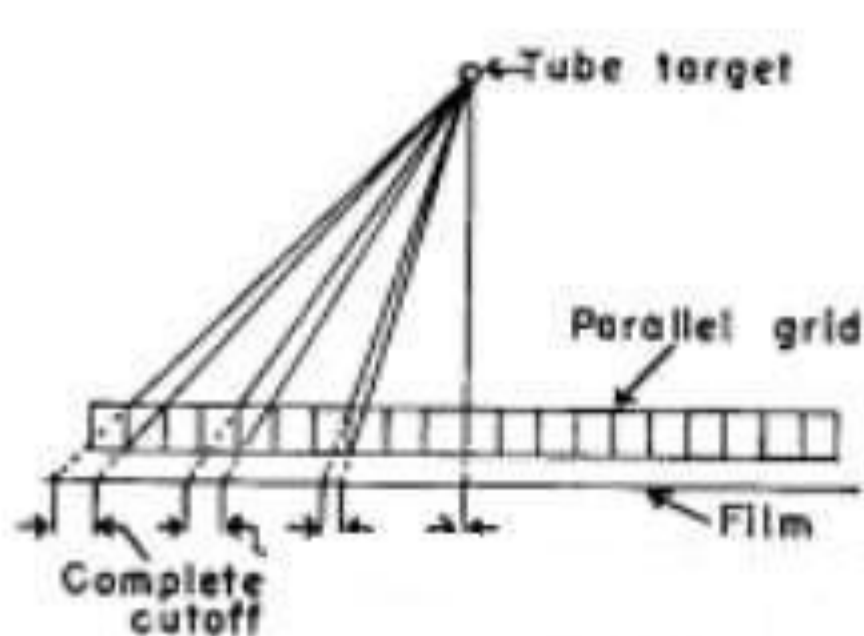
- Parallel
- Focused



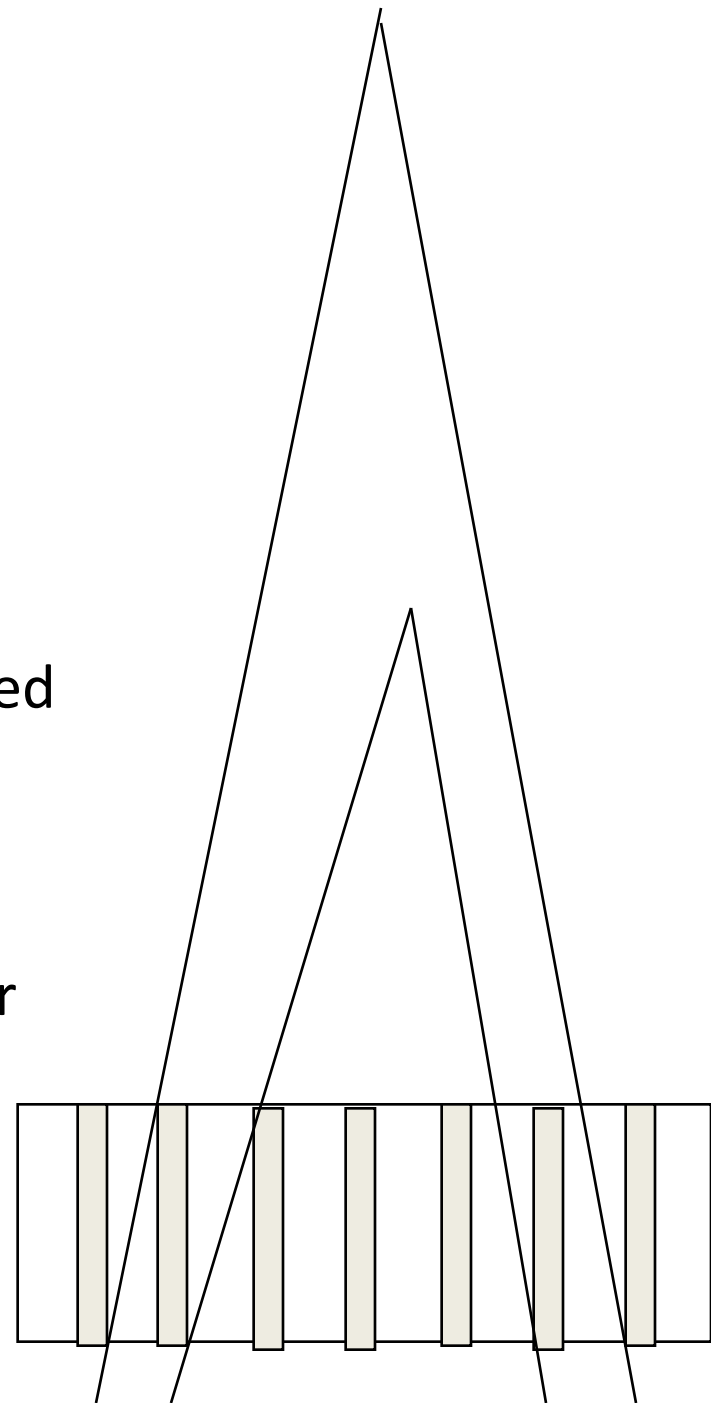
Parallel= unfocused Grid

- lead strips are parallel to each other and to the central beam
 - Strips are never aligned with primary beam since all are vertical (except for strips directly under central ray)





- Primary rays will be increasingly attenuated until at an angle of “angle of acceptance”, where complete cut-off will occur
- Restricted maximum beam size
- This effect can be reduced by using longer FFD
- Used for:
 - small field sizes
 - large FFD



Focused Grid

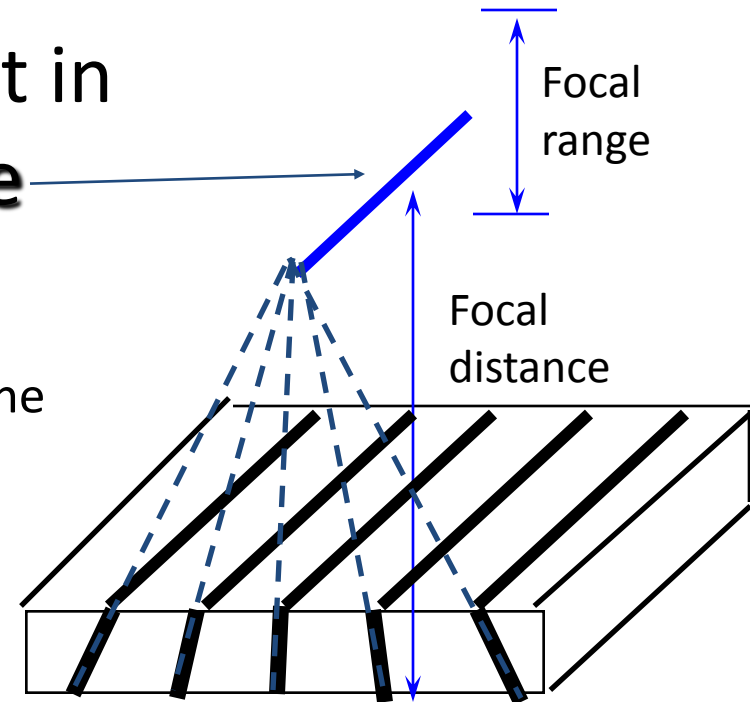
- Strips are angled progressively from center to the edge of the grid



- Strip lines converge to a point in space called **convergence line**

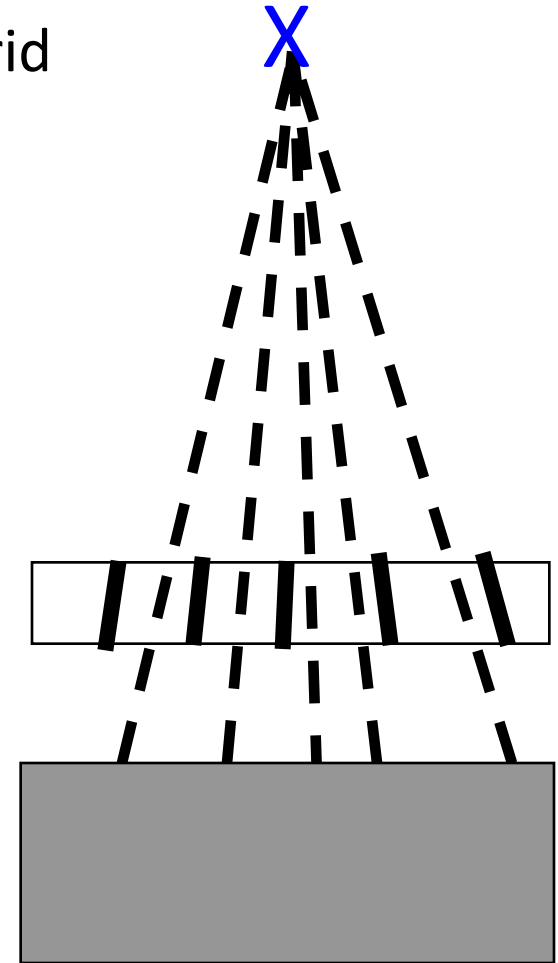
- Focal distance

- distance from convergence line to grid plane



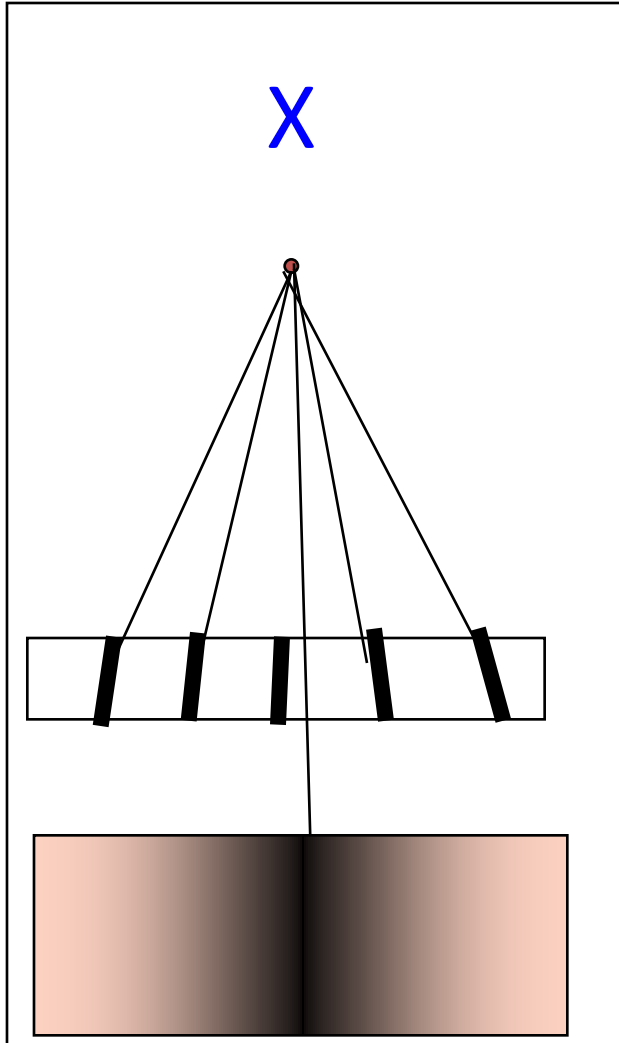
Conditions for using focused grid (otherwise cut-off of primary ray will happen)

- 1) Grid must not be tilted about the axis of the lead strips
- 2) Distance between grid and anode = focal distance
- 3) Tube must be accurately centered over the grid
- 4) Grid must not be turned upside-down



N.B: these tolerances reduce with higher grid ratios

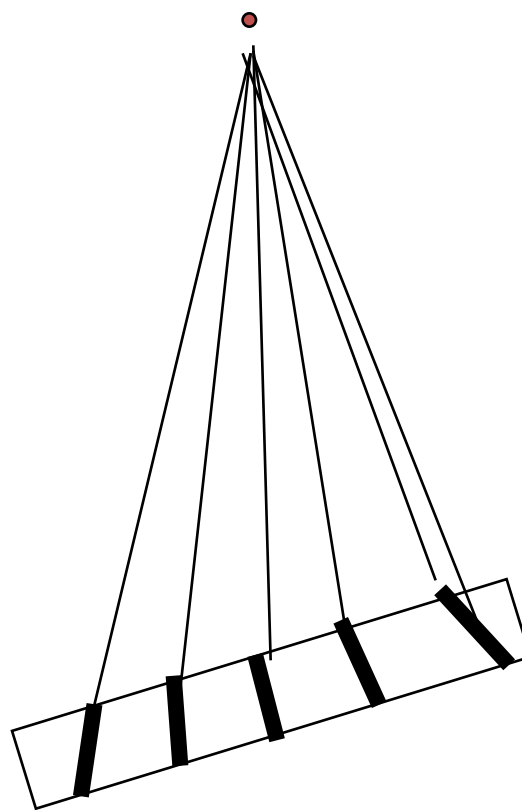
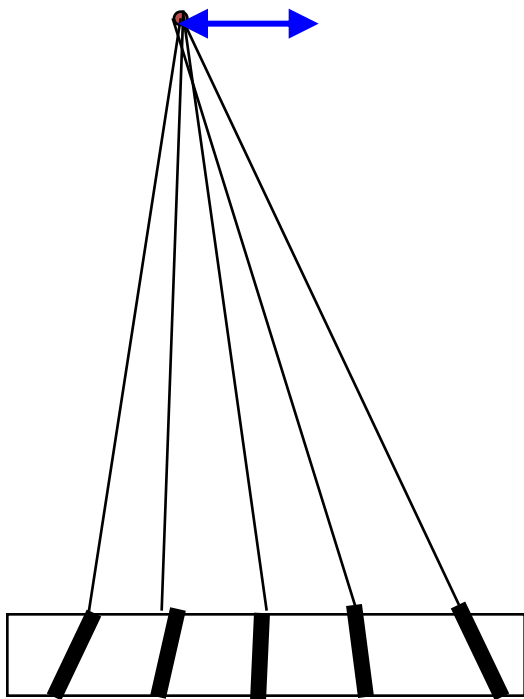
Distance Decentering



- Grid too close or too far from focal spot
- Darker center

Lateral Decentering

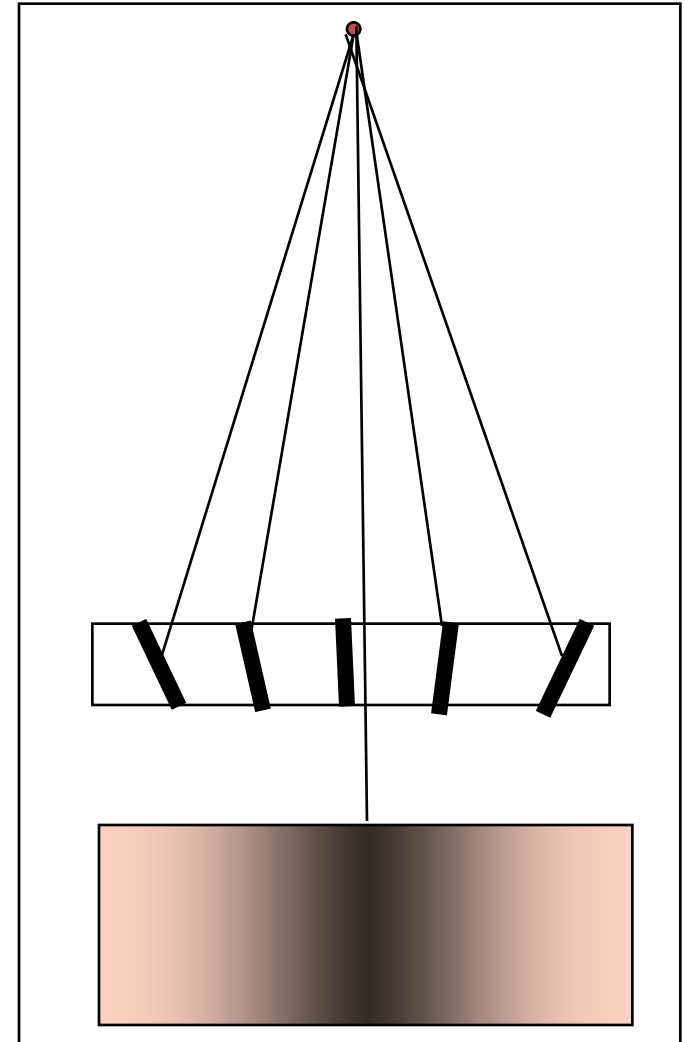
- occurs when tube is not accurately centered over the grid OR when the grid is tilted
- result in uniform loss of intensity
 - may be mistaken for technique problems and compensated for by over-exposing patient



N.B: Tube can be angled along the length of lead strips without cut-off of the primary beam

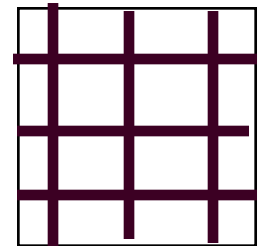
Upside Down Focused Grid

- Dark exposed band in center
- Severe peripheral cutoff



N.B: Cross hatched Grids

- 2 stacked linear grids
- ratio is sum of ratios of two linear grids
- very sensitive to positioning & tilting
- Rarely used



Stationary Grids

- Grids which does not move
- Grid lines : shadows of lead strips superimposed on radiological image
→ reduces detail definition (disadvantage of stationary grid)

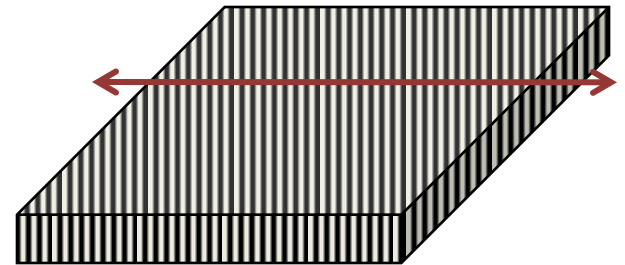
Stationary grids must be used in some situation (e.g. ward radiography)

→ grids should have increased line density to decrease grid line artifact



Moving grids:

- move during exposure → blur out grid lines
- Direction of Movement :
perpendicular to grid lines
- Motion starts before the exposure start and does not stop until the exposure is terminated



Moving Grid Disadvantages

- Increases patient dose
 - lateral decentering from motion
 - up to 20% loss of primary
 - evenly distributes radiation on film
 - stationary grid makes interspace gaps darker for same amount of radiation

Grid Performance Measurements

- contrast improvement factor
- Primary Transmission
- Bucky Factor
- Grid selectivity

Contrast Improvement Factor

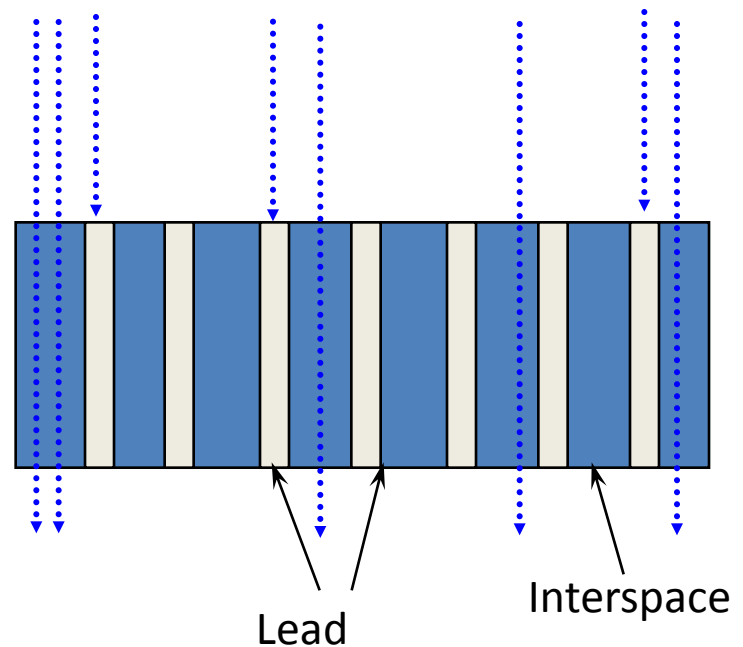
- Ratio of contrast with & without grid
- Usually 2-4
- Depends on :
 - grid ratio (increase Contrast Improvement Factor)
 - lead content in grid (increase Contrast Improvement Factor)

Contrast Improvement Factor

- Depends also on factors affecting relative amount of scatter
 - kVp
 - field size
 - Tissue thickness
- increase in any of above →
 - more scatter
 - less contrast
 - lower contrast improvement factor

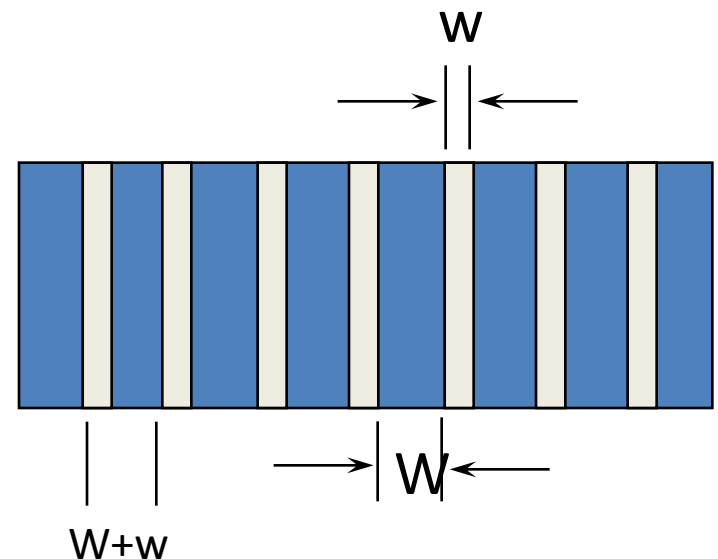
Primary Transmission

- Fraction of a scatter-free beam passed by grid
- Ideally 100% (never achieved)



Primary Transmission

- Upper limit of primary transmission = fraction of the interspaces = $W / (W+w)$
- actual transmission < upper limit
 - primary attenuated by interspace material
 - focusing imperfections
- Typical values: 55 - 75%



Bucky Factor

Radiation incident on grid

transmitted radiation

- Measures fraction of radiation absorbed by grid
- Higher bucky factor → higher patient's dose (mA must be increased)
- high ratio grids have higher bucky factors

N.B: Grid factor =

Exposure necessary with a grid

Exposure necessary without a grid

Both = 3-5

Grid selectivity

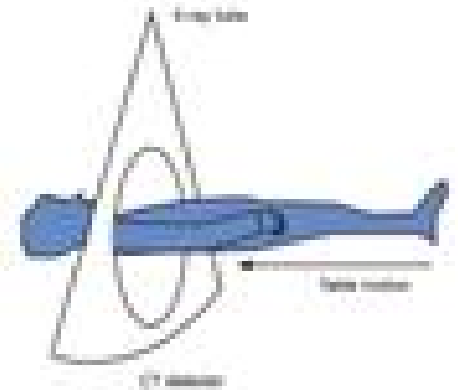
$$\frac{\text{Fraction of primary radiation transmitted}}{\text{Fraction of secondary radiation transmitted}} = 6-12$$

Grid Tradeoff

- Advantage
 - scatter rejection
- Disadvantage
 - \uparrow mA \rightarrow increased patient dose
 - increase tube loading
 - increased exposure time
 - positioning & centering more critical

Scanned projection radiography

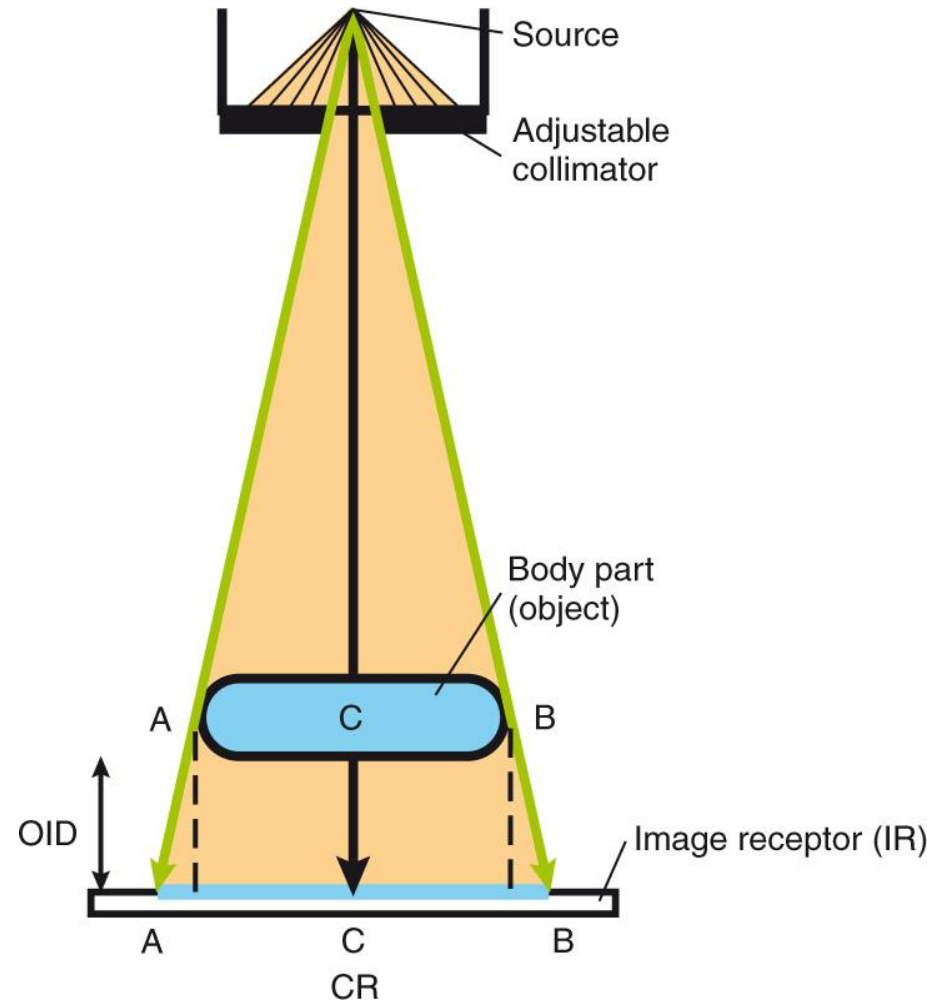
- Alternative to grid
- Moving slot collimator (Slice of the patient is irradiated at a time)
- Scatter is reduced due to decrease of the radiation field
- See CT and digital radiology



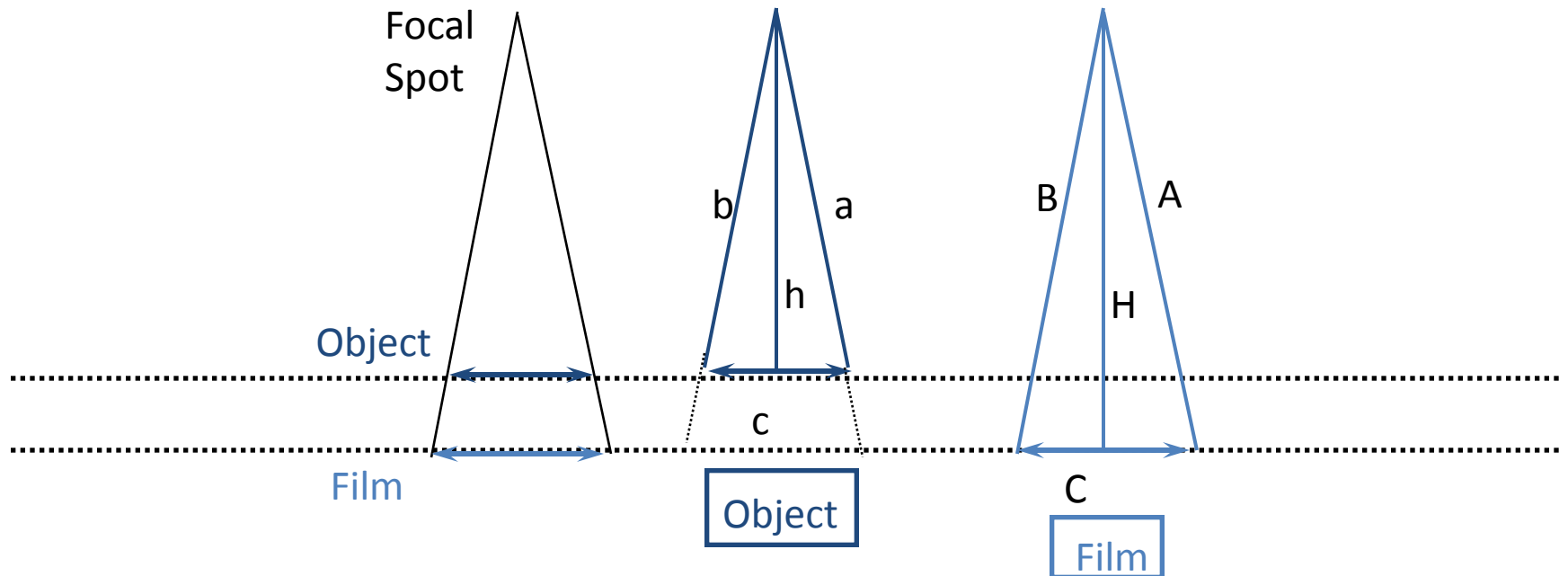
Geometry of the Radiographic System

1)Magnification

- Misrepresentation of object size
- Due to X-ray beam divergence

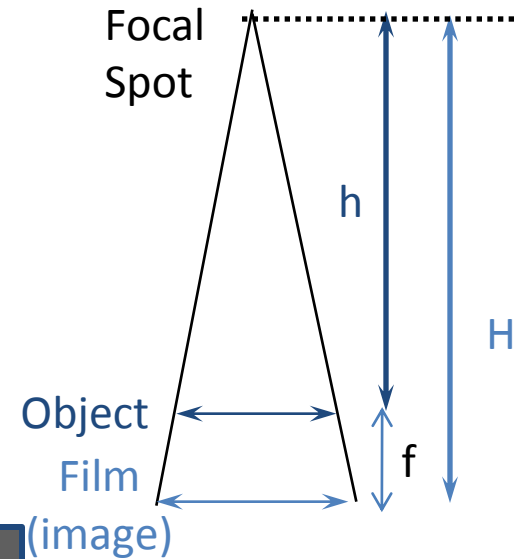


Magnification



a	b	c	h
----	=	----	=
A	B	C	H

$$\text{Magnification} = \frac{\text{size of image}}{\text{size of object}}$$



$$\text{Magnification} = \frac{\text{focus to film distance}}{\text{focus to object distance}} = \frac{H}{h}$$

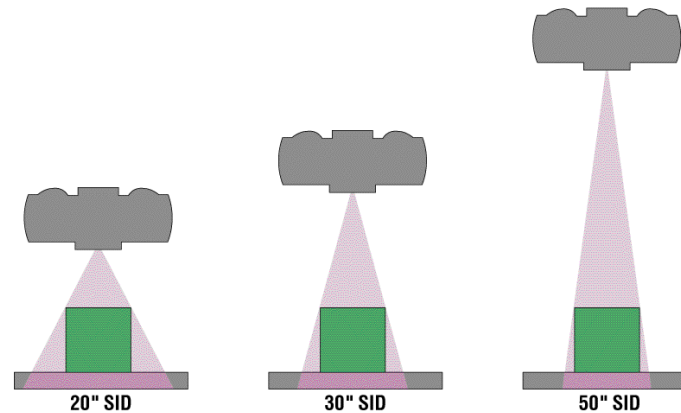
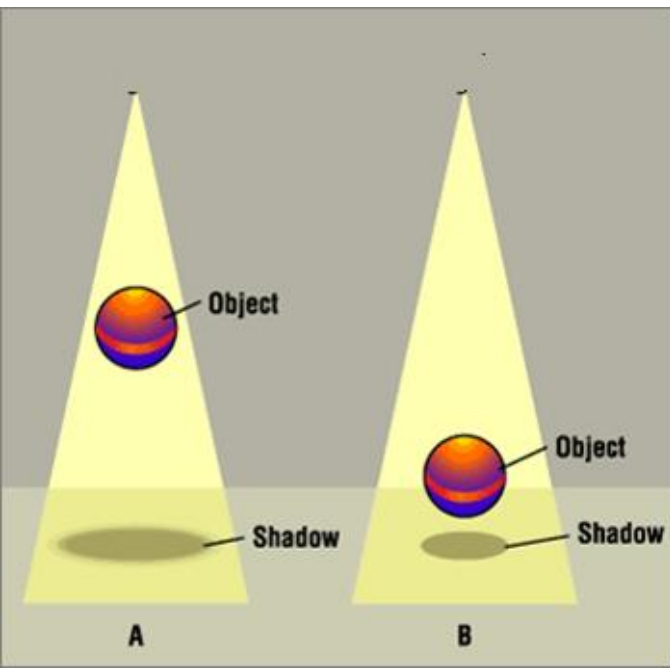
$$\text{Magnification} = \frac{\text{focus to film distance}}{\text{focus to film distance} - \text{object film distance}} = \frac{H}{H-f}$$

*

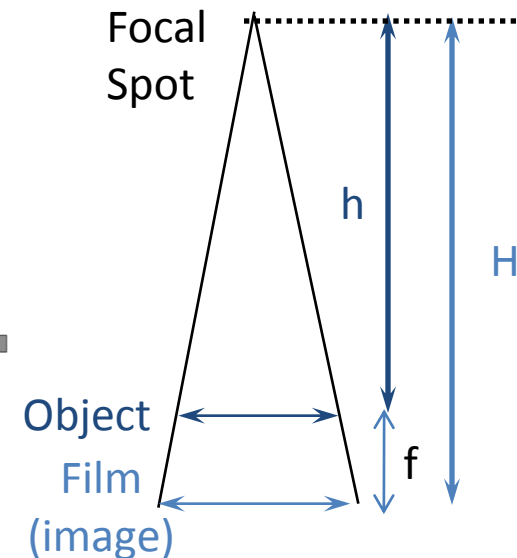
Optimizing Image Quality

$$\text{Magnification} = \frac{\text{focus to film distance}}{\text{focus to film distance} - \text{object film distance}} = \frac{H}{H-f}$$

- So that : to Minimize magnification
 - 1) Minimize object-film distance
 - 2) Maximize focal-film distance (disadvantages: \uparrow mAs \rightarrow \uparrow tube load & motion)

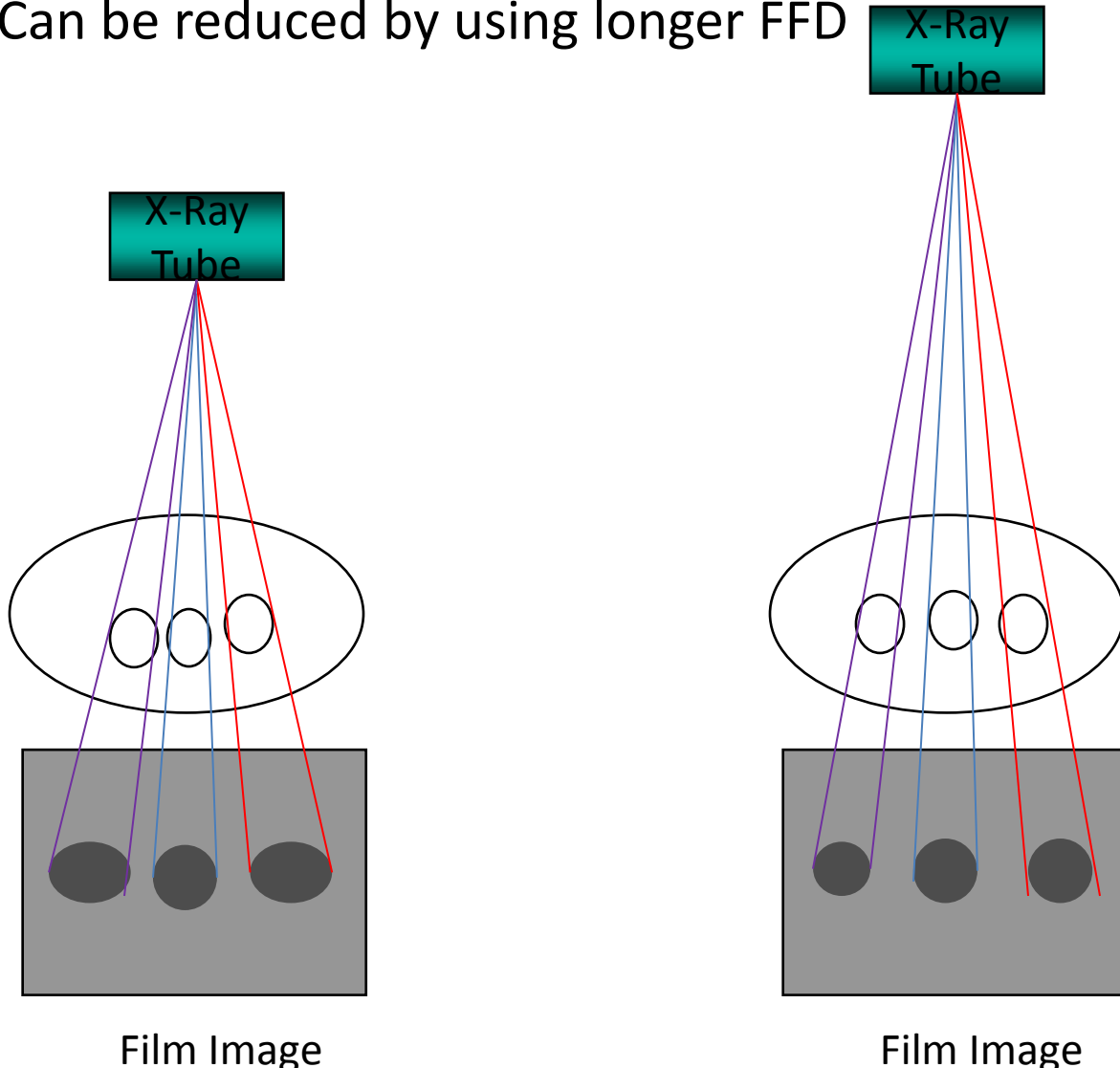


A longer SID decreases magnification.
A shorter SID increases magnification.



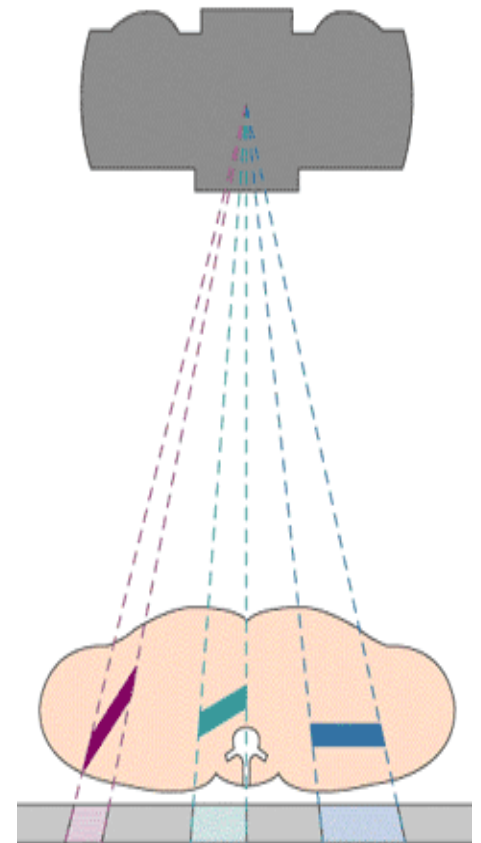
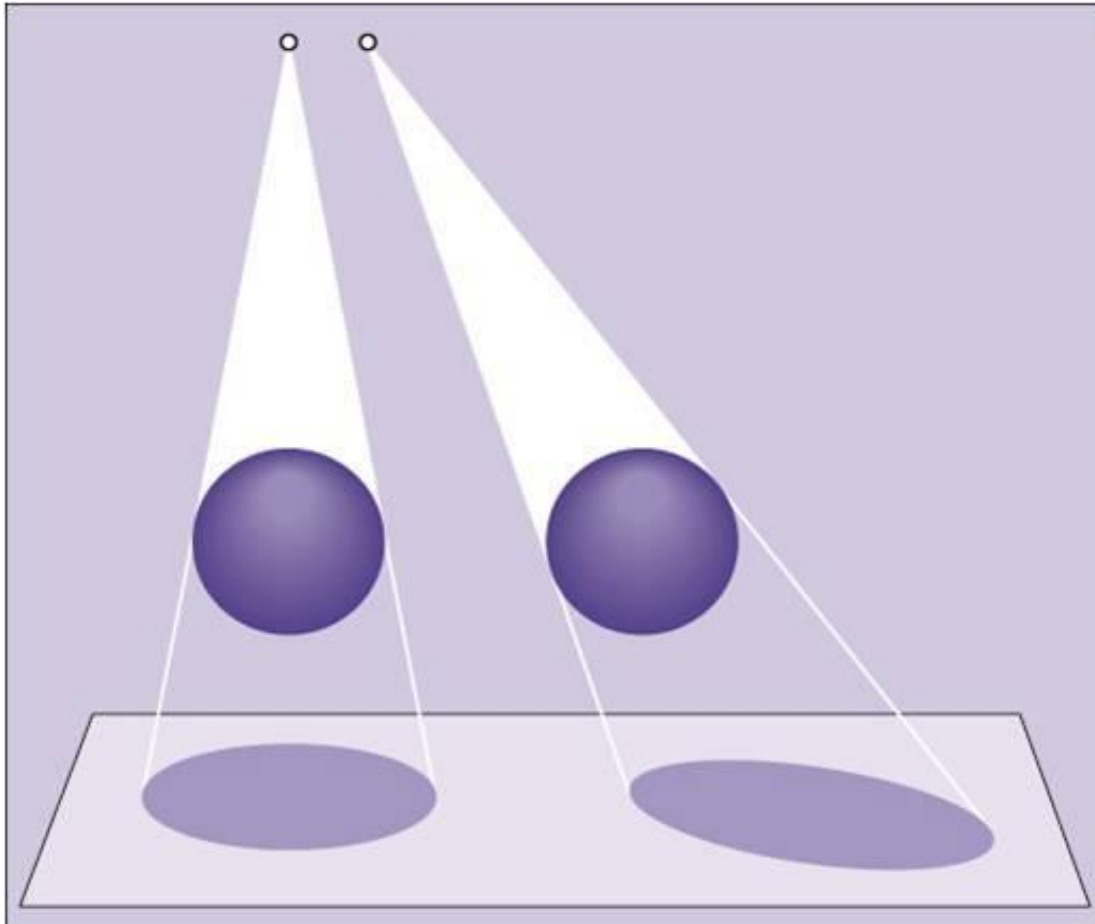
2) Distortion

- Misrepresentation of the shape of an object
- Minimal distortion when object near central beam & close to film
- Can be reduced by using longer FFD



Distortion

- Increased by Central ray angulation & body part rotation

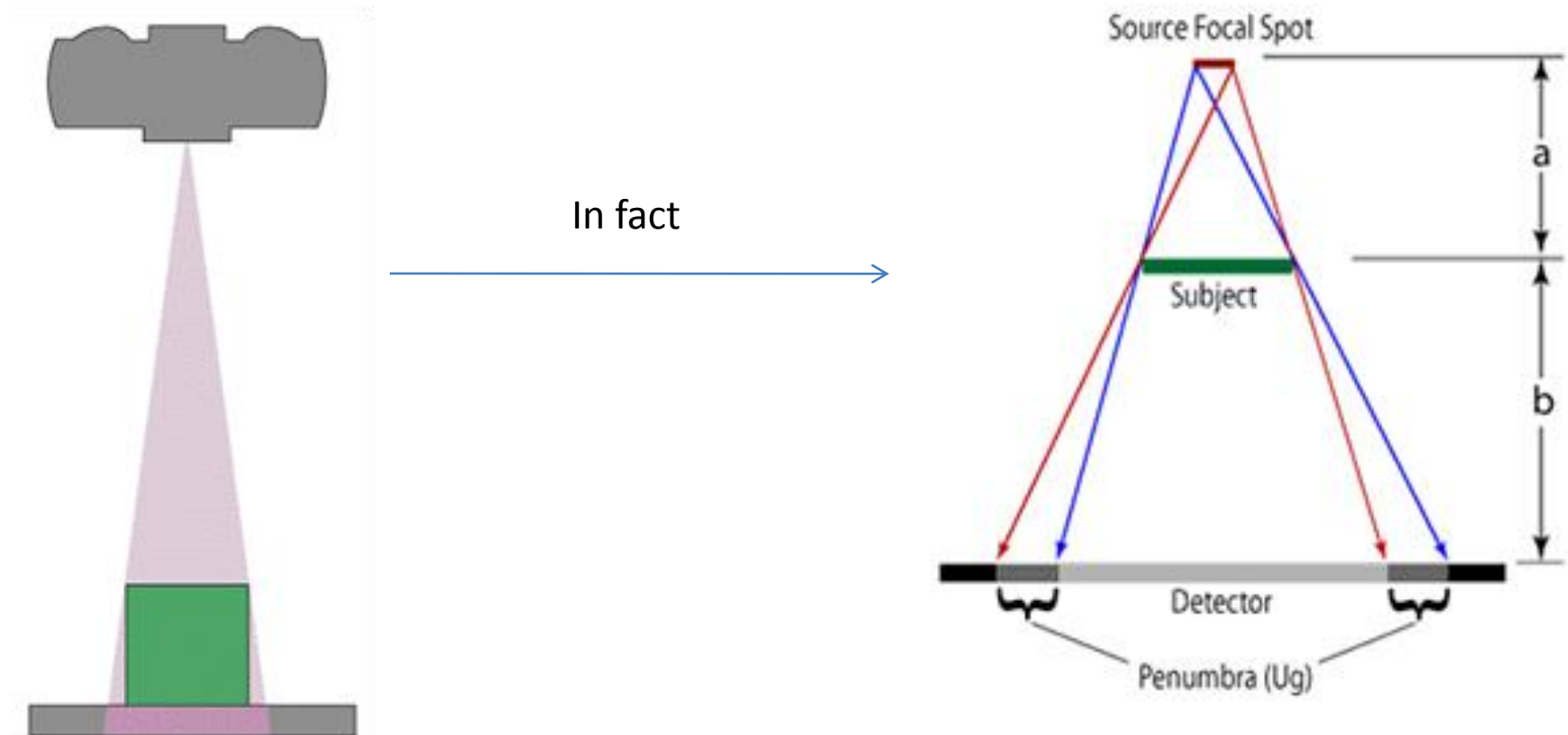


3)Sharpness

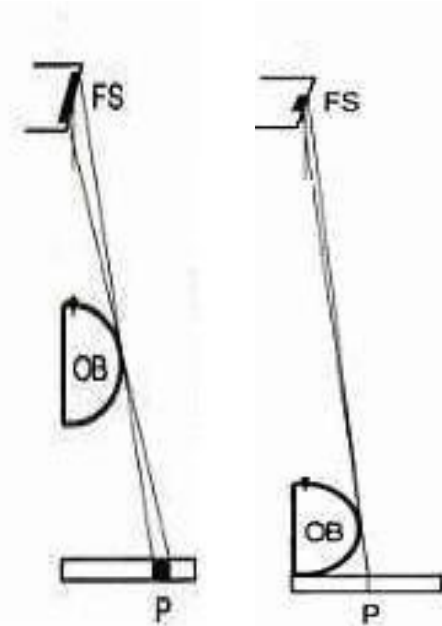
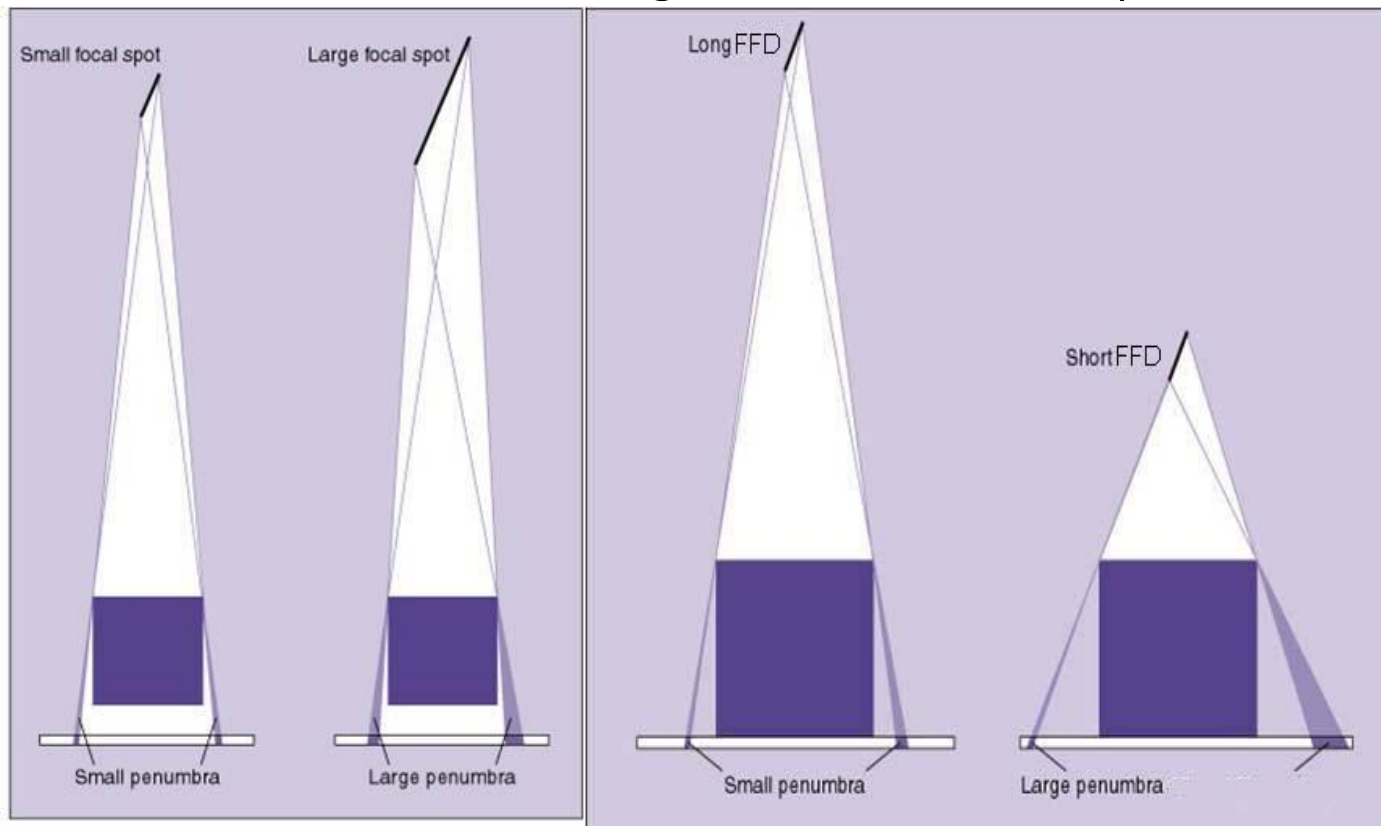
- Ability of receptor to define an edge
- Unsharpness = blurred edges → decreased spatial resolution
- Causes of unsharpness:
 - 1) Geometrical unsharpness
 - 2) Movement unsharpness
 - 3) Absorption unsharpness

Geometrical unsharpness

- X ray intensity at the edge of an object changes gradually over a distance = penumbra



Factors affecting Geometrical unsharpness



1)Focal spot size: increase focal spot size → increase unsharpness

2)FFD : increase film focus distance → decrease unsharpness

3)OFD: increase object film distance → increase unsharpness

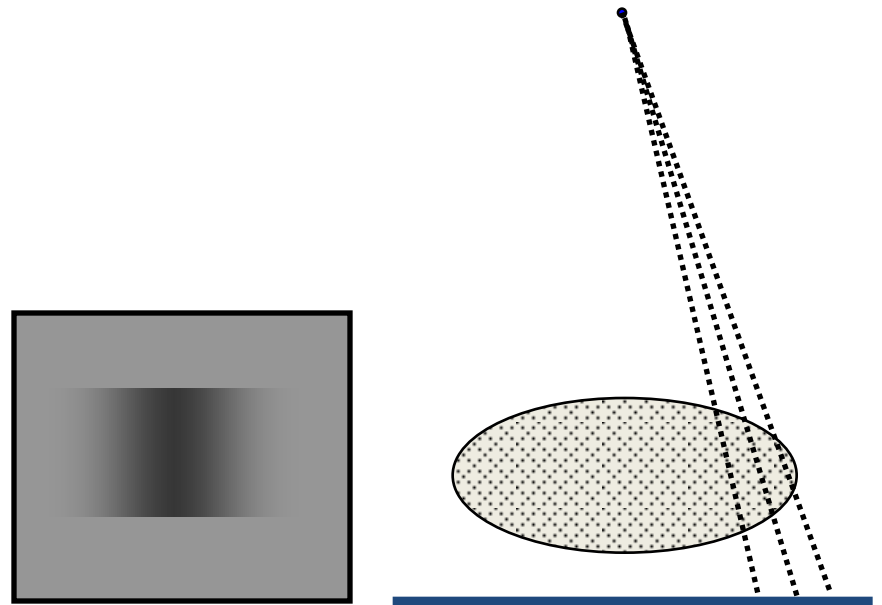
$$\text{Equation: geometric unsharpness } U_g (\text{penumbra}) = \frac{\text{OFD} \times \text{Focal spot size}}{\text{FFD} - \text{OFD}}$$

Motion Unsharpness

- Caused by motion during exposure of
 - patient
 - tube
 - film
- Effect
 - Edge unsharpness
- Minimized by
 - immobilizing patient
 - short exposure times (t)
- Equation: motion unsharpness (U_m) = $v t$
V=velocity of moving object
t = exposure time

Absorption unsharpness

- Absorber may not have sharp edges
 - round or oval objects
- This leads to gradual change in x-ray absorption across an object's edge Effect → Edge unsharpness

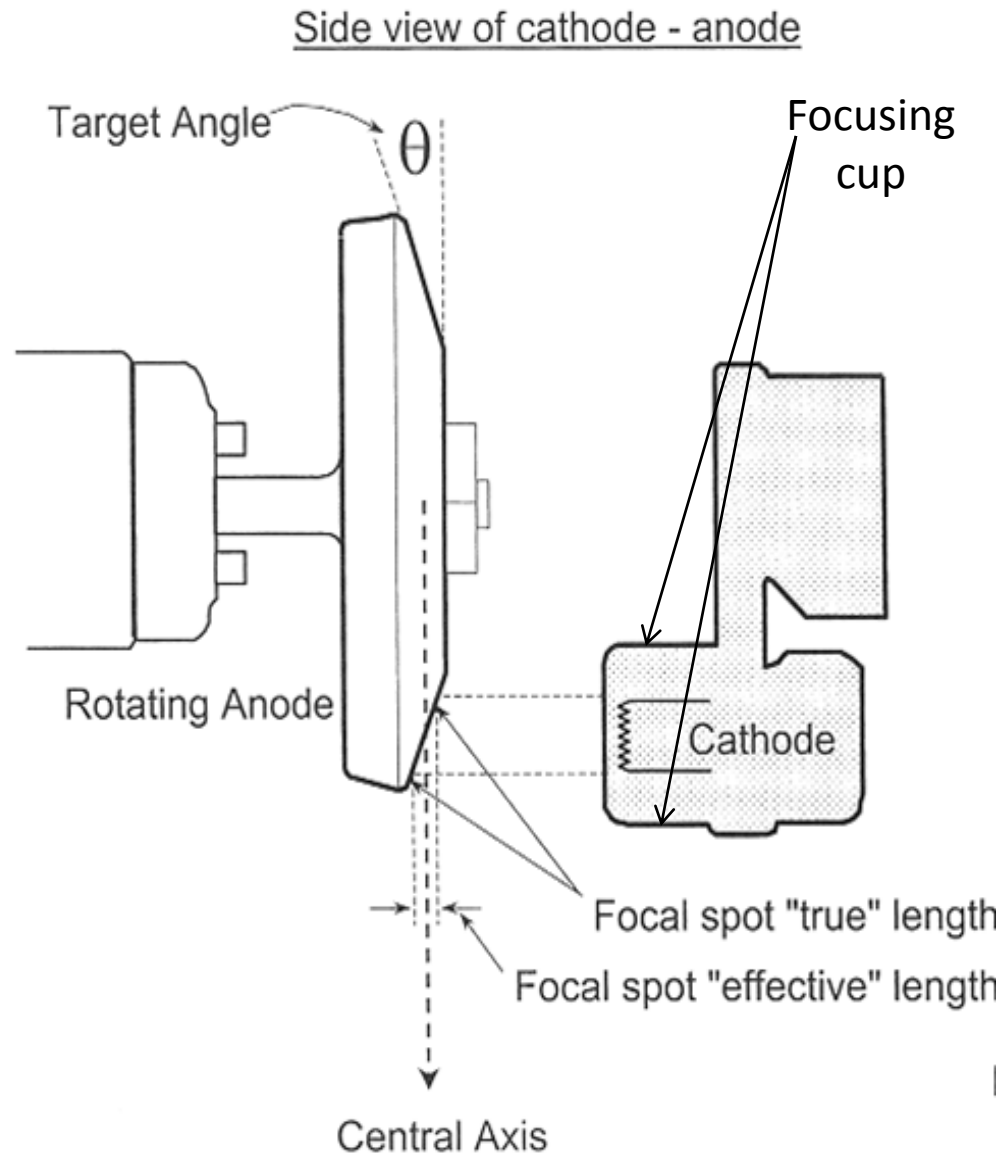


Total Unsharpness

- combination of all the above
BUT
not the sum!
- larger than largest component
- largest component controls unsharpness
 - improvement in smaller components don't help much

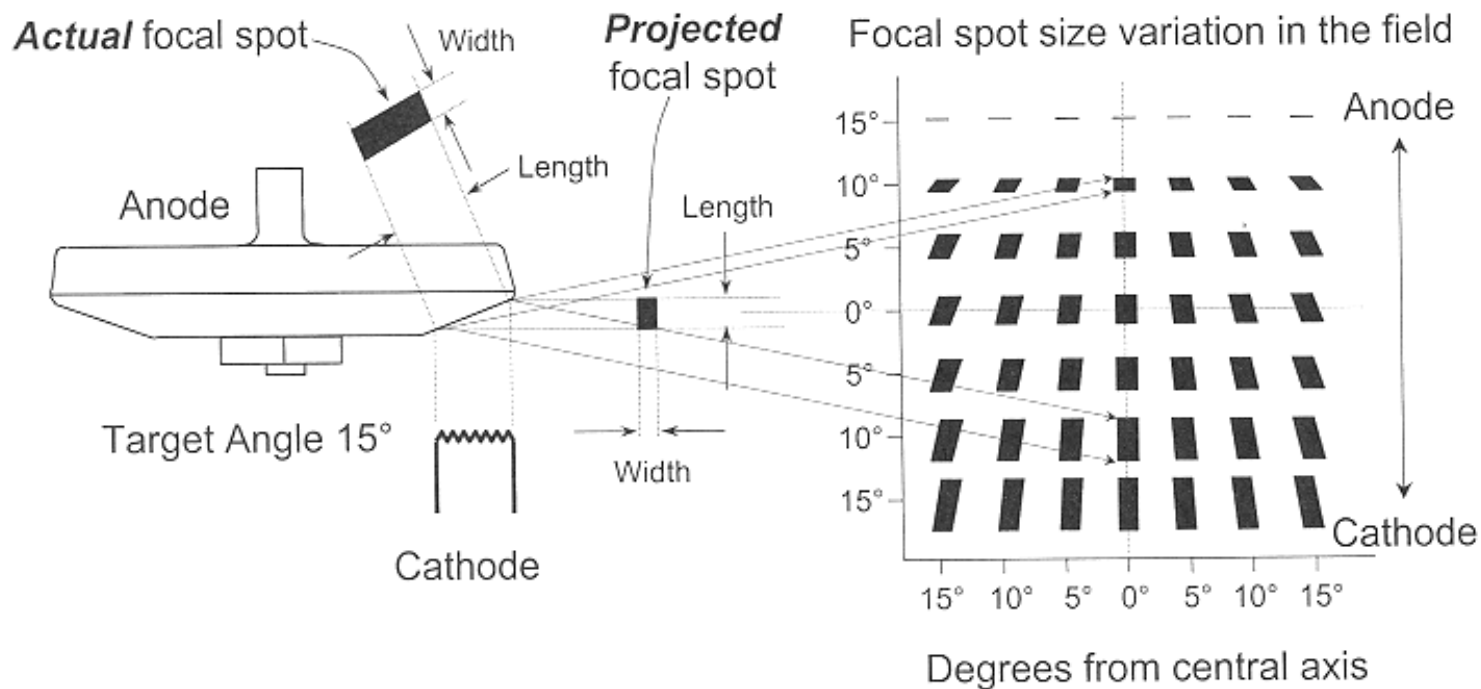
focal spot

Focal spot



Definitions:

- 1) Focusing cup : negatively charged device that surrounds the filament on the cathode side of the x-ray tube to prevent electrons from being emitted in all directions (mutually repellant)
 - 2) Target angle: angle between central ray of x-ray beam and target face ($7-20^\circ$)
 - 3) Actual (true) focal spot: area on the target face on which electrons are focused , it has elongated shape (area over which the heat is produced)
 - 4) Effective focal spot: the projected focal spot area, as seen from the centre of the X-ray field
- It is foreshortened in one direction (in relation to actual focal spot) \rightarrow appear circular or elliptical



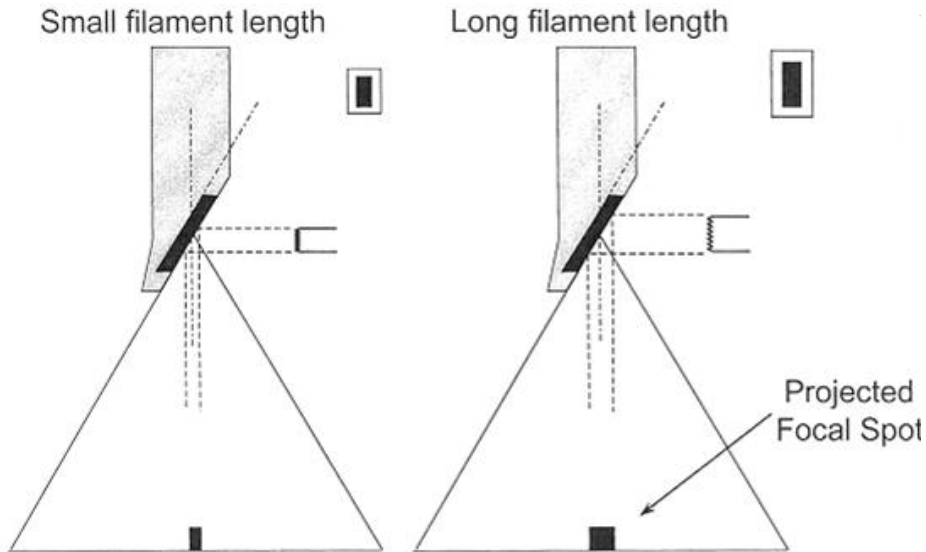
Note that :

Shape of effective focal spot size varies across the film

when seen from cathode side → elongated in the direction of anode cathode axis

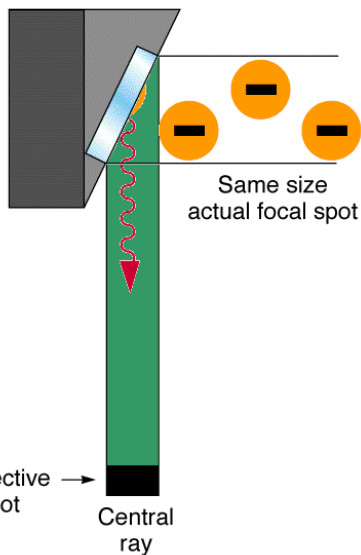
when seen from anode side → shortened in the direction of anode cathode axis

Factors affecting size of effective focal spot

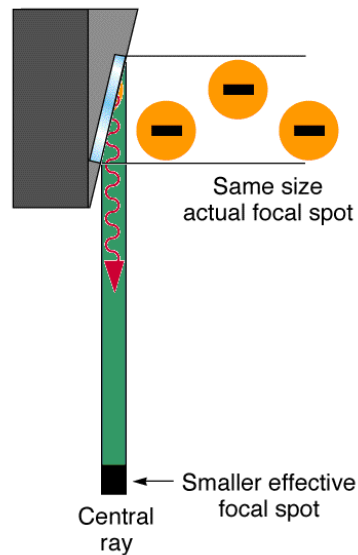


1) \uparrow Filament length $\rightarrow \uparrow$ actual and effective focal spot

24° Angle Anode



12° Angle Anode



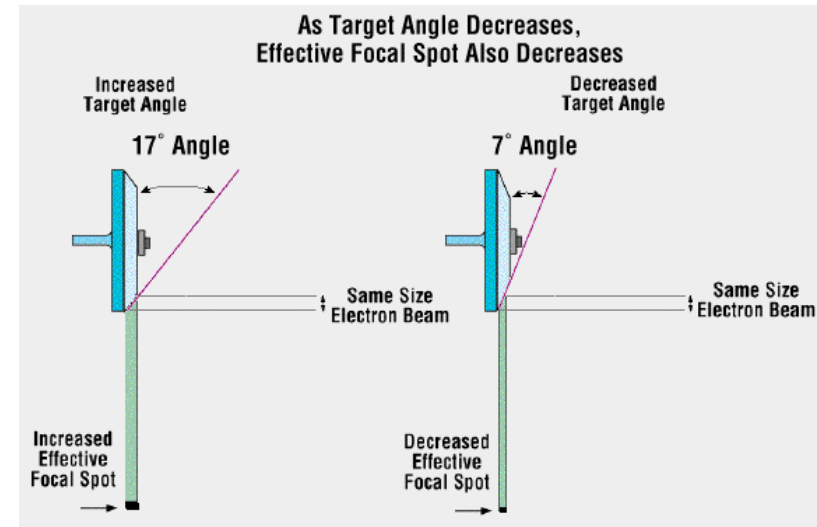
2) \uparrow target angle $\rightarrow \uparrow$ effective focal spot (no effect on actual focal spot)

Effects of steeper target angle

1) Decrease effective focal spot size (without changing actual focal spot)→

- Decrease geometrical unsharpness → ↑ spatial resolution
- limits field coverage

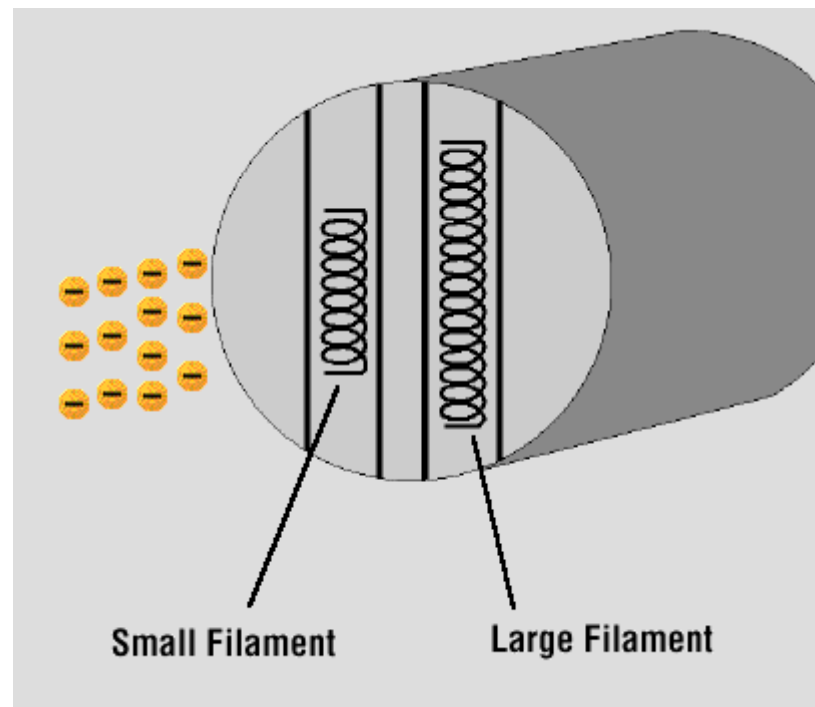
(Good for mammo)



2) Increase the actual focal spot size (to produce the same effective focal spot size) → increased heat production ☹

Double Focus Tubes

- Large Filament (2.0 mm): larger effective focal spot - used for larger body parts - loses some detail.
- Small Filament (0.3 mm): smaller effective focal spot - used for small body parts such as extremity and detect fine detail.



Focal spot blooming

- Increased tube current (mA) → impaired focusing of the electron → unwanted increase in focal spot size
- More significant for lower kVp settings

- measurement focal spot size
(quality control)

a) **Slit camera**

b) **Pin hole camera:**

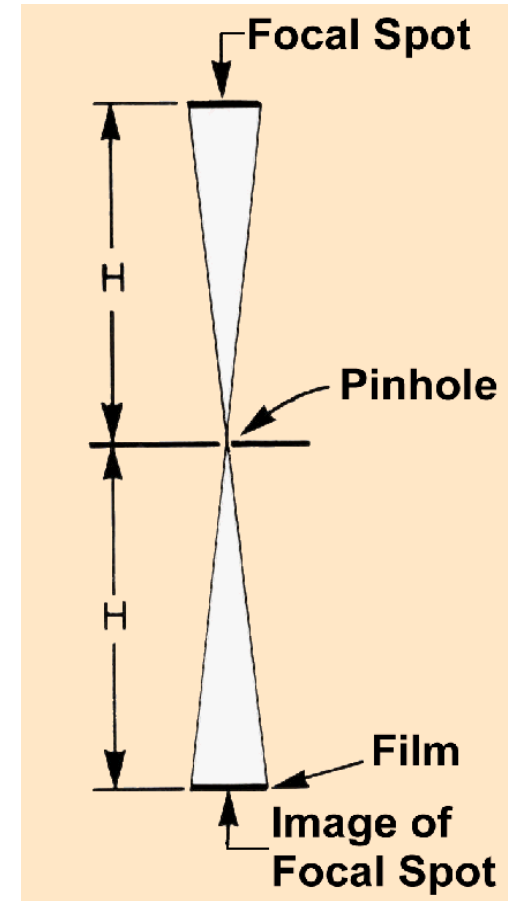
Direct measurement of focal spot size

Used for focal spot size > 0.3 mm

c) **Star test tool :**

Indirectly measure focal spot size

Used for focal spot size < 0.3 mm



Anode types

Anode types

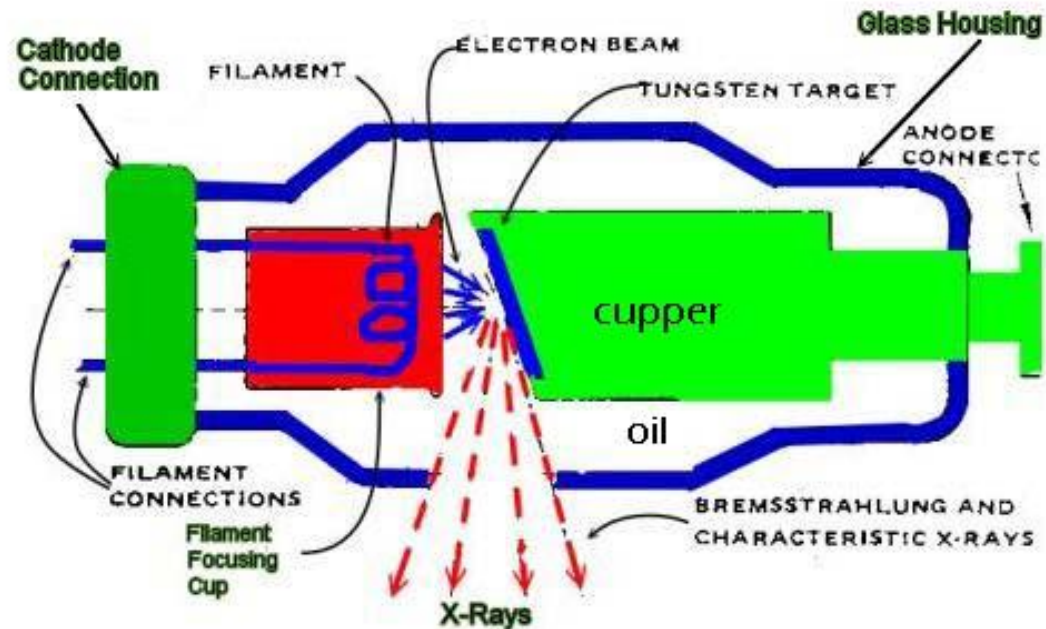
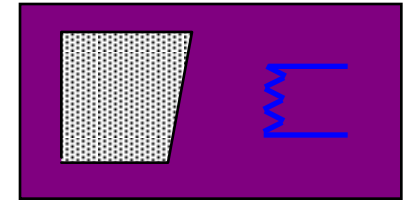
- 1) Stationary anode

- Discussed before (made of tungsten)

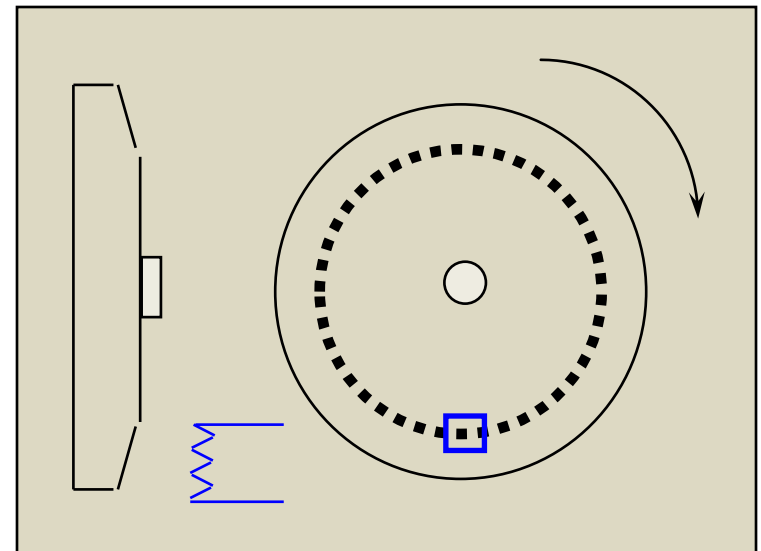
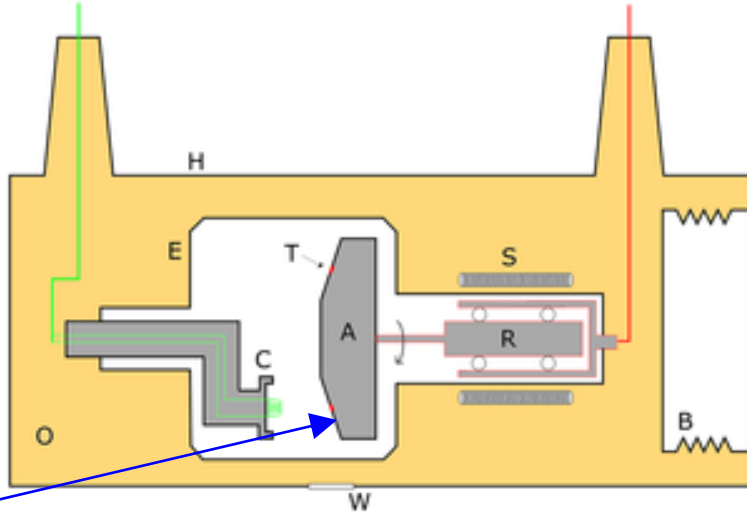
- Stationary anode cooling methods

- Heat is transferred from anode to copper block by conduction

- Heat then passes through the oil to tube housing & to the room



- Rotating anode
 - Target is annular rotating disc
 - Advantage :spreads heat over large area of anode
 - Circumference of anode disc : 200-300 mm
 - Rotation speed 3000 rpm (full rotation takes 20 ms)
 - High speed anodes energized by three phase mains
→ 9000 rpm



- Consists of:

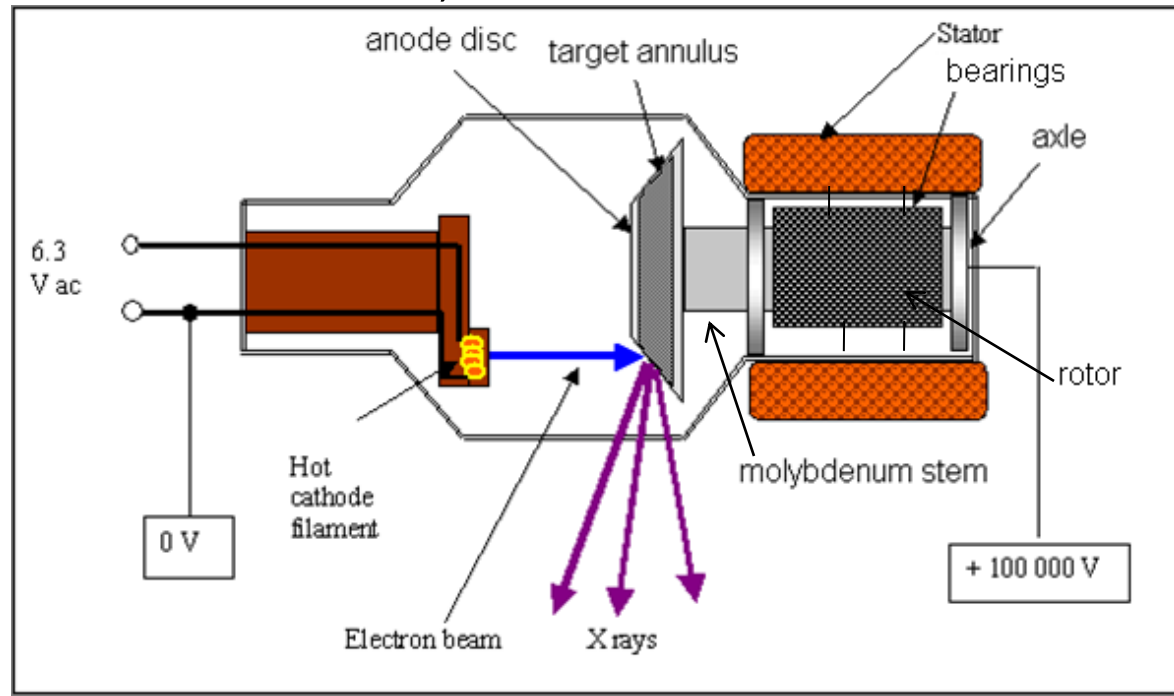
- 1) Anode disc: 7-10 cm in diameter, made of molybdenum (high melting point and low density)
- 2) Target annulus : Alloy of tungsten and rhenium (better thermal characteristics than tungsten alone)
- 3) Molybdenum stem
- 4) Copper rotor
- 5) Bearings : lubricated with soft metal (e.g. silver) to enable rotor to rotate freely
- 6) axle: Support the assembly
- 7) Stator coils: induction motor which drive rotation , without direct mechanical linkage to rotating parts

Stator alternating currents

→ produce varying magnetic

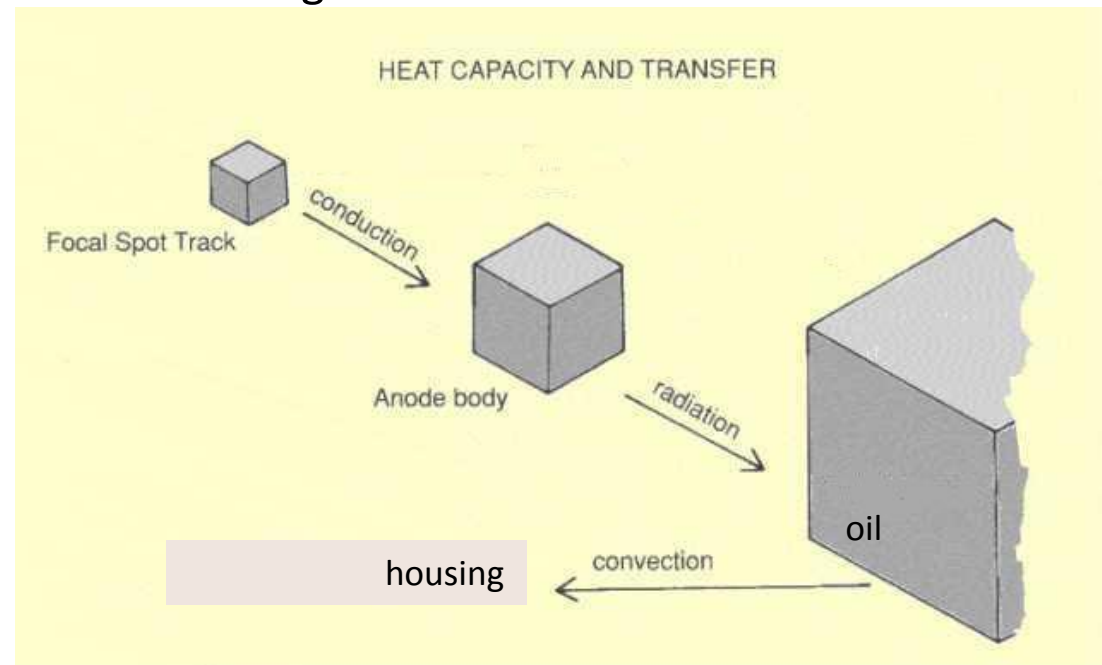
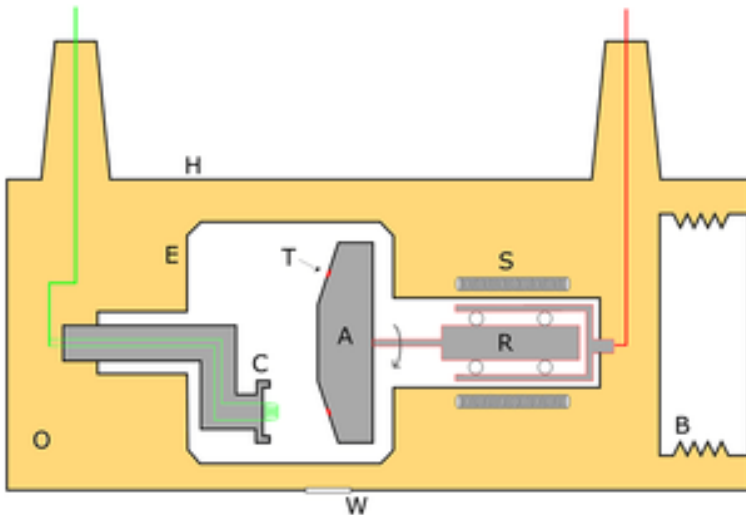
fields → induce rotor currents

N.B: Time delay of 1 s is present before anode comes to full speed (no mechanical linkage)



Rotating anode cooling

- Heat from target is conducted to anode disc and molybdenum stem
 - Molybdenum stem is long and narrow and has low conduction rate \rightarrow control amount of heat conducted to the rotor
- Heat transferred by radiation from anode to the oil
 - Rate of heat radiation $\propto \text{temperature}^4$ (in Kelvin)
this means that 40% increase in x ray output \rightarrow 10% only increase in temperature
- Heat is transferred by convection from oil to the housing
 - External heat exchanger may pump new oil in high powered tubes (e.g. angio)
 - Bellow system is present to allow oil expansion when heated
- The heat is transferred by radiation From housing to air



- N.B: Most of tubes used in radiology are rotating anode tubes except:

1-Dental radiology

2-Mobile fluoroscopy units

3-Ward radiography

X-Ray Beam Restrictors

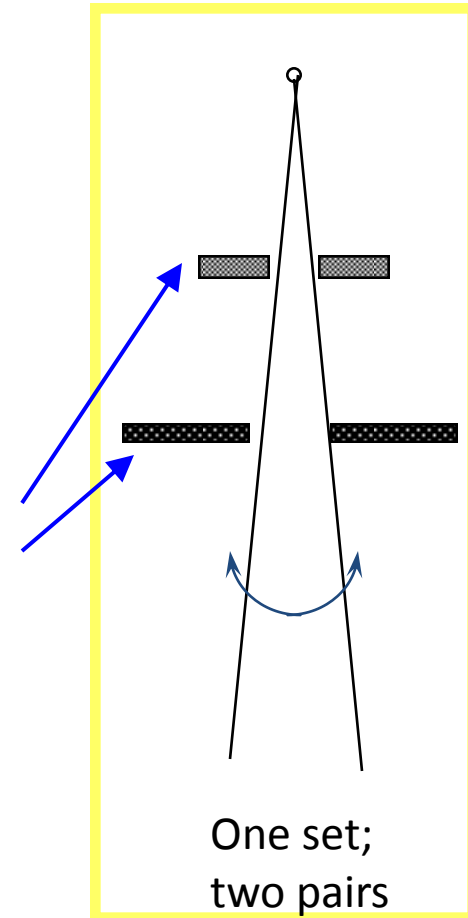
Restrictors Types

- Aperture Diaphragms (leads to large penumbra)
- Cones and Cylinders (Reduced Penumbra)
- Collimators

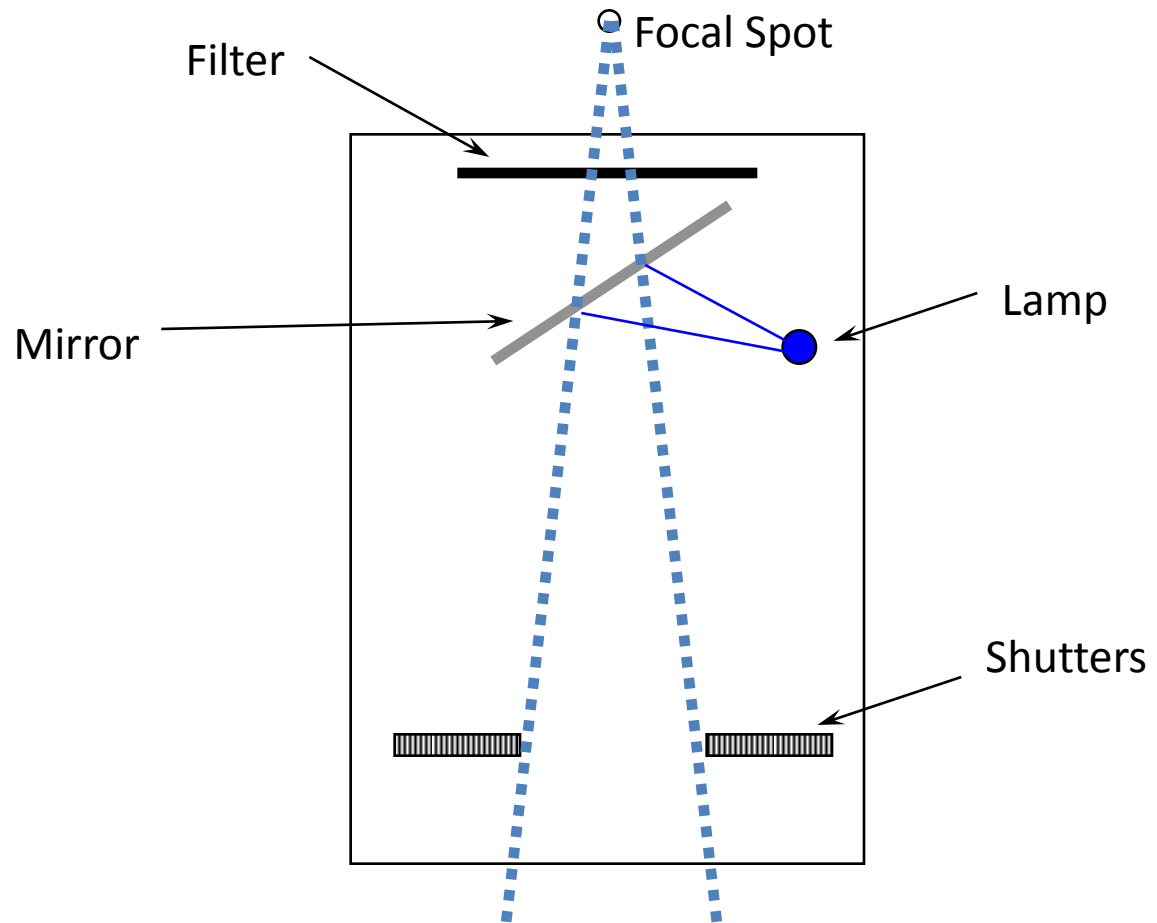


Collimators

- Function:
 - Adjust X-ray beam to the required size
 - Provides adjustable rectangular field
 - fluoroscopy may also have circular field
- Consists of
 - Two sets of parallel plates (shutters) of high Z material



- light beam indicates x-ray field

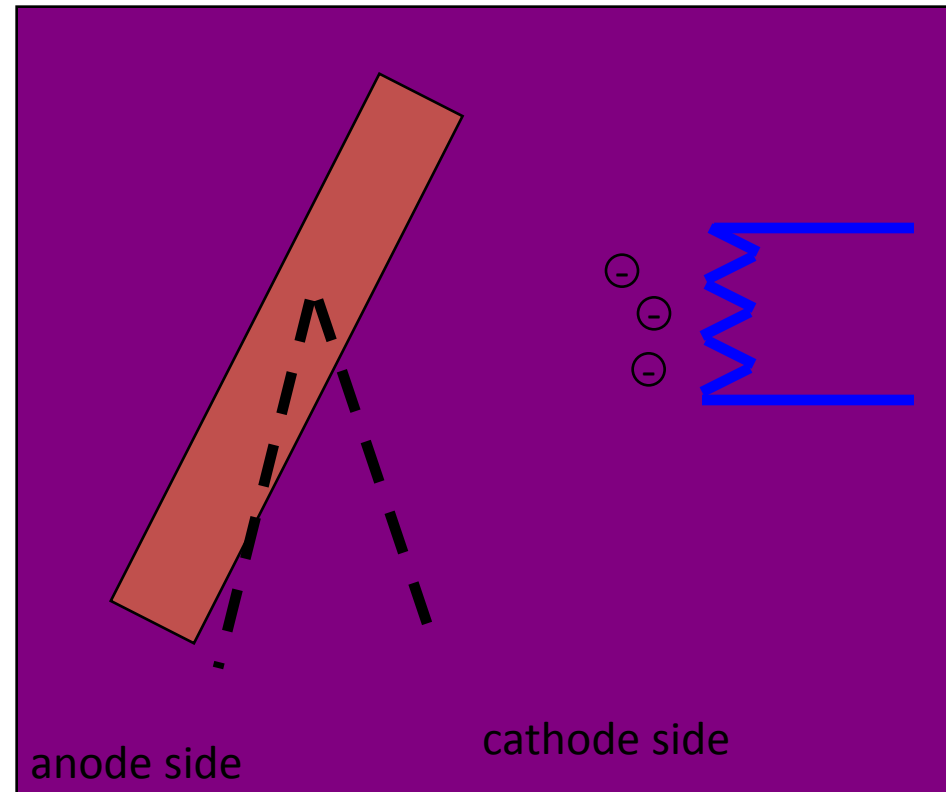


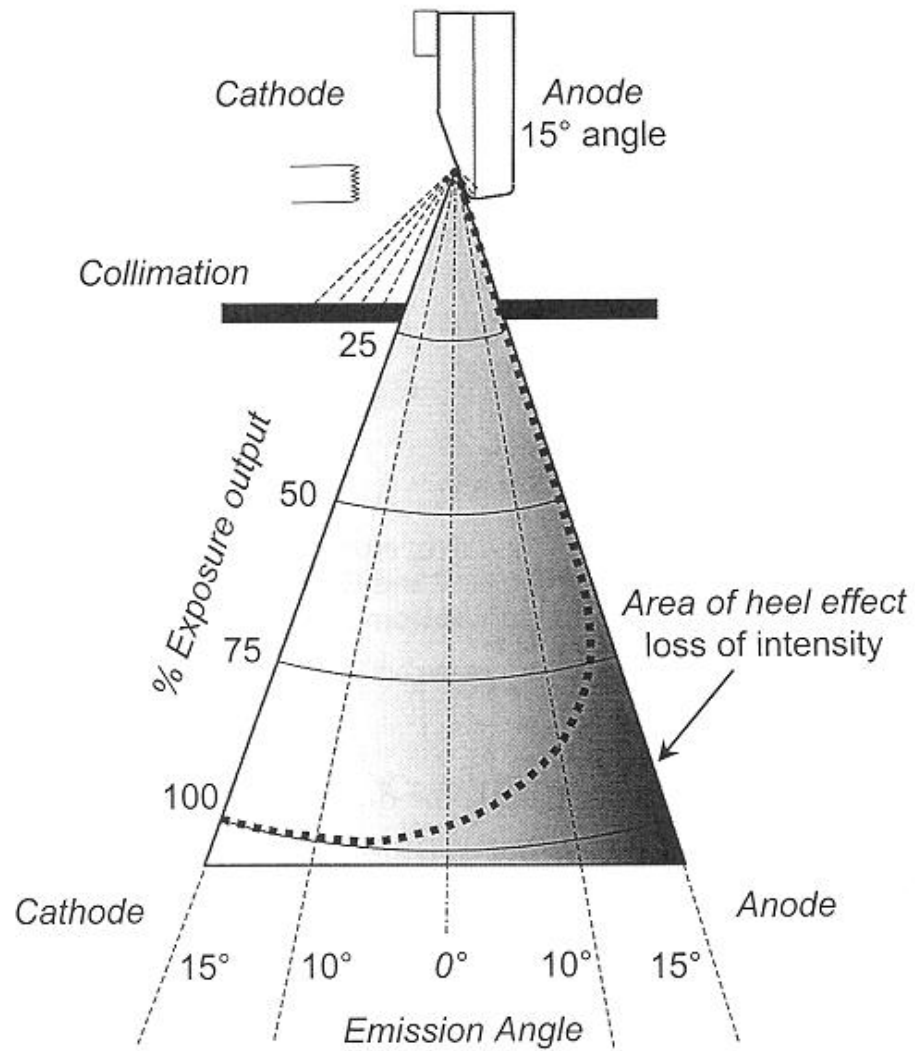
Advantages

- 1) decrease scatter
- 2) decrease patient dose
- 3) improve image quality

Heel Effect

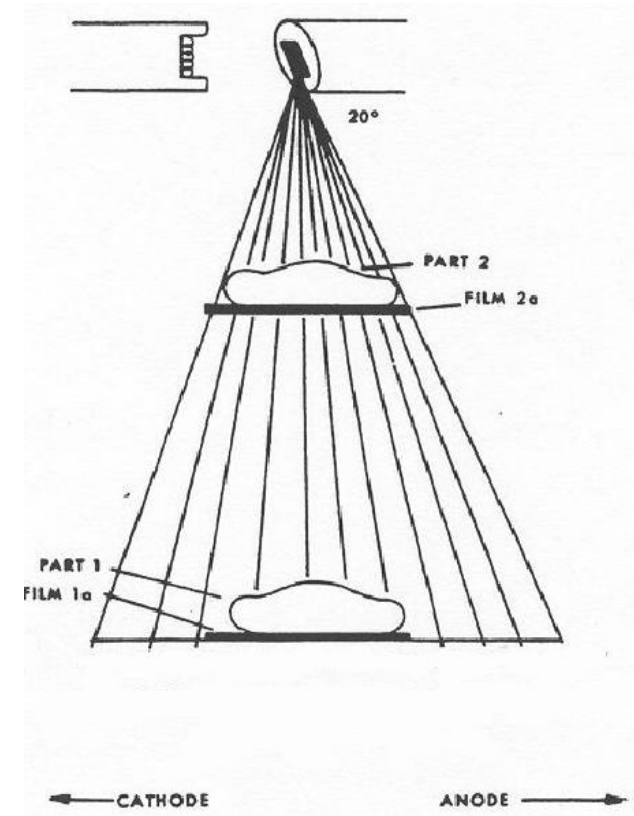
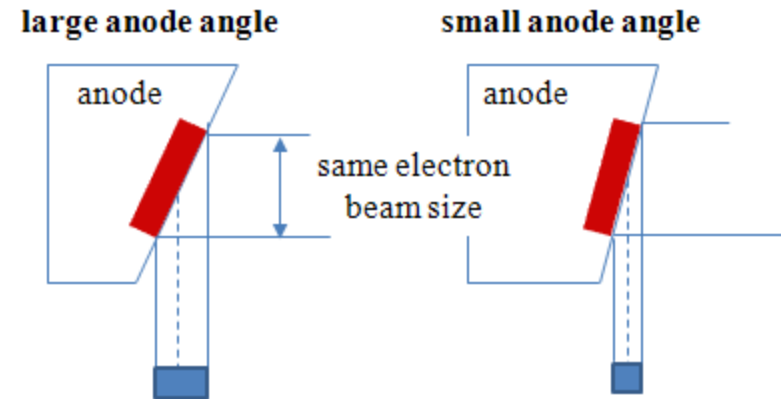
- beam goes through more target material while exiting the anode
- Intensity of x-ray beam significantly reduced on anode side
- HVL of beam at anode side is increased (filtered) ... less imp





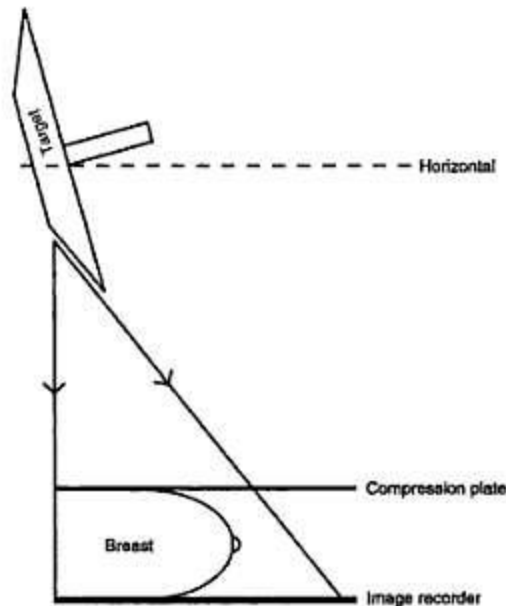
Factors affecting Heel effect

- 1) target angle: decrease target angle (steeper) → more heel effect
- 2)FFD: \uparrow FFD → less heel effect
- 3)Aging of the tube → rough target surface → more heel effect



The Heel Effect

- X-ray tube best positioned with the cathode over the thicker parts of the patient to balance the transmitted x-ray photons incident on the image receptor



THANK YOU